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(54) **Biocompatible scaffold for ligament or tendon repair**

Körperverträgliches Stützgerüst zur Wiederherstellung von Bändern oder Sehnen

Support biocompatible pour la réparation des ligaments ou tendons

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to biocompatible tissue implant devices for use in the repair of tissue injuries, as well as methods for making and using such biocompatible tissue implant devices.

BACKGROUND OF THE INVENTION

[0002] Injuries to soft tissue, such as cartilage, skin, muscle, bone, tendon and ligament, where the tissue has been injured or traumatized frequently require surgical intervention to repair the damage and facilitate healing. Such surgical repairs can include suturing or otherwise repairing the damaged tissue with known medical devices, augmenting the damaged tissue with other tissue, using an implant, a graft or any combination of these techniques.

[0003] One common tissue injury involves damage to cartilage, which is a non-vascular, resilient, flexible connective tissue. Cartilage typically acts as a "shock-absorber" at articulating joints, but some types of cartilage provide support to tubular structures, such as for example, the larynx, air passages, and the ears. In general, cartilage tissue is comprised of cartilage cells, known as chondrocytes, located in an extracellular matrix, which contains collagen, a structural scaffold, and aggrecan, a space-filling proteoglycan. Several types of cartilage can be found in the body, including hyaline cartilage, fibrocartilage and elastic cartilage. Hyaline cartilage can appear in the body as distinct pieces, or alternatively, this type of cartilage can be found fused to the articular ends of bones. Hyaline cartilage is generally found in the body as articular cartilage, costal cartilage, and temporary cartilage (*i.e.*, cartilage that is ultimately converted to bone through the process of ossification). Fibrocartilage is a transitional tissue that is typically located between tendon and bone, bone and bone, and/or hyaline cartilage and hyaline cartilage. Elastic cartilage, which contains elastic fibers distributed throughout the extracellular matrix, is typically found in the epiglottis, the ears and the nose.

[0004] One common example of hyaline cartilage injury is a traumatic focal articular cartilage defect to the knee. A strong impact to the joint can result in the complete or partial removal of a cartilage fragment of various size and shape. Damaged articular cartilage can severely restrict joint function, cause debilitating pain and may result in long term chronic diseases such as osteoarthritis, which gradually destroys the cartilage and underlying bone of the joint. Injuries to the articular cartilage tissue will not heal spontaneously and require surgical intervention if symptomatic. The current modality of treatment consists of lavage, removal of partially or completely unattached tissue fragments. In addition, the surgeon will often use a variety of methods such as abrasion, drilling or microfractures, to induce bleeding into the cartilage defect and formation of a clot. It is believed that the cells coming from the marrow will form a scar-like tissue called fibrocartilage that can provide temporary relief to some symptoms.

Unfortunately, the fibrocartilage tissue does not have the same mechanical properties as hyaline cartilage and degrades faster over time as a consequence of wear. Patients typically have to undergo repeated surgical procedures which can lead to the complete deterioration of the cartilage surface. More recently, experimental approaches involving the implantation of autologous chondrocytes have been used with increasing frequency. The process involves the harvest of a small biopsy of articular cartilage in a first surgical procedure, which is then transported to a laboratory specialized in cell culture for amplification. The tissue biopsy is treated with enzymes that will release the chondrocyte cells from the matrix, and the isolated cells will be grown for a period of 3 to 4 weeks using standard tissue culture techniques. Once the cell population has reached a target number, the cells are sent back to the surgeon for implantation during a second surgical procedure. This manual labor-intense process is extremely costly and time consuming. Although, the clinical data suggest long term benefit for the patient, the prohibitive cost of the procedure combined with the traumatic impact of two surgical procedures to the knee, has hampered adoption of this technique.

[0005] One common example of cartilage injury is damage to the menisci of a knee joint. There are two menisci of the knee joint, a medial and a lateral meniscus. Each meniscus is a biconcave, fibrocartilage tissue that is interposed between the femur and tibia of the leg. In addition to the menisci of the knee joint, meniscal cartilage can also be found in the acromioclavicular joint, *i.e.*, the joint between the clavicle and the acromion of the scapula, in the sternoclavicular joint, *i.e.*, the joint between the clavicle and the sternum, and in the temporomandibular joint, *i.e.*, the joint of the lower jaw. The primary functions of meniscal cartilage are to bear loads, to absorb shock and to stabilize a joint. If not treated properly, an injury to the meniscus, such as a "bucket-handle tear" in the knee joint, may lead to the development of osteoarthritis. Current conventional treatment modalities for damaged meniscal cartilage include the removal and/or surgical repair of the damaged cartilage.

[0006] Another common form of tissue injury involves damage to the ligaments and/or tendons. Ligaments and tendons are cords or bands of fibrous tissue that contains soft collagenous tissue. Ligaments connect bone to bone, while tendons connect muscle to bone. Tendons are fibrous cords or bands of variable length that have considerable strength but are virtually devoid of elasticity. Ligaments, in contrast, are generally pliant and flexible, to allow the ligament tissue to have freedom of movement, and simultaneously strong and inextensible, to prevent the ligament tissue from readily yielding under applied force. Ligaments and tendons are comprised of fascicles, which contain the basic fibril of the ligament or

tendon, as well as the cells that produce the ligament or tendon, known as fibroblasts. The fascicles of the tendon are generally comprised of very densely arranged collagenous fibers, parallel rows of elongated fibroblasts, and a proteoglycan matrix. The fascicles of ligaments also contain a proteoglycan matrix, fibroblasts and collagen fibrils, but the fibrils found in ligament tissue are generally less dense and less structured than the fibrils found in tendon tissue.

[0007] One example of a common ligament injury is a torn anterior cruciate ligament (ACL), which is one of four major ligaments of the knee. The primary function of the ACL is to constrain anterior translation, rotary laxity and hyperextension. The lack of an ACL causes instability of the knee joint and leads to degenerative changes in the knee such as osteoarthritis. The most common repair technique is to remove and discard the ruptured ACL and reconstruct a new ACL using autologous bone-patellar, tendon-bone or hamstring tendons. Although this technique has shown long-term clinical efficacy, there is morbidity associated with the harvest site of the tissue graft. Synthetic prosthetic devices have been clinically evaluated in the past with little long-term success. The advantages of a synthetic implant are that the patient does not suffer from the donor site morbidity that is associated with autograft procedures, and that patients having a synthetic implant are able to undergo faster rehabilitation of the knee. These synthetic devices were composed of non-resorbable materials and were designed to be permanent prosthetic implants. A number of problems were found during the clinical trials of these implants, such as for example, synovitis, bone tunnel enlargement, wear debris, and elongation and rupture of the devices. For this reason, autograft reconstruction is still the widely accepted solution for repairing a ruptured ACL.

[0008] A common tendon injury is a damaged or torn rotator cuff, which is the portion of the shoulder joint that facilitates circular motion of the humerus bone relative to the scapula. The most common injury associated with the rotator cuff is a strain or tear to the supraspinatus tendon. This tear can occur at the insertion site of the supraspinatus tendon, where the tendon attaches to the humerus, thereby partially or fully releasing the tendon (depending upon the severity of the injury) from the bone. Additionally, the strain or tear can occur within the tendon itself. Treatment for a strained tendon usually involves rest and reduced use of the tendon. However, depending upon the severity of the injury, a torn tendon may require surgical intervention, such as for example, in the case of a full tear of the supraspinatus tendon from the humerus. In the case of severe tendon damage, surgical intervention can involve the repair and/or reattachment of torn tissue, which typically requires a healing and recovery period.

[0009] There is a continuing need in this art for novel surgical techniques for the surgical treatment of damaged tissue (*e.g.*, cartilage, meniscal cartilage, ligaments, tendons and skin) that can effect a more reliable repair of tissue and can facilitate the healing of damaged tissue. Various surgical implants are known and have been used in surgical procedures to help achieve these benefits. For example, it is known to use various devices and techniques for creating implants having isolated cells loaded onto a delivery vehicle. Such cell-seeded implants are used in an *in vitro* method of making and/or repairing cartilage by growing cartilaginous structures that consist of chondrocytes seeded onto biodegradable, biocompatible fibrous polymeric matrices. Such methods require the initial isolation of chondrocytes from cartilaginous tissue prior to the chondrocytes being seeded onto the polymeric matrices. Other techniques for repairing damaged tissue employ implants having stem or progenitor cells that are used to produce the desired tissue. For example, it is known to use stem or progenitor cells, such as the cells within fatty tissue, muscle, or bone marrow, to regenerate bone and/or cartilage in a patient. The stem cells are removed from the patient and placed in an environment favorable to cartilage formation, thereby inducing the fatty tissue cells to proliferate and to create a different type of cell, such as for example, cartilage cells.

[0010] US2002/062151A discloses a method for producing a bioengineered anterior cruciate ligament comprising seeding pluripotent stem cells in a cylindrical collagen matrix. US4597766A discloses bioprosthetic tendons and ligaments comprising an isolated cross-linked animal tendon or ligament having attached thereto at least one decalcified bone chip.

[0011] There continues to exist a need in this art for novel devices and methods for making and/or repairing damaged tissue and for hastening the healing of the damaged tissue.

SUMMARY OF THE INVENTION

[0012] This invention relates to biocompatible tissue implants, as defined in claim 1, for use in treating tissue. For example, the tissue implants can be used for the repair and/or regeneration of diseased or damaged tissue. Further, the tissue implants can be used for tissue bulking, cosmetic treatments, therapeutic treatments, tissue augmentation, and tissue repair. The implants include a biocompatible scaffold that is associated with at least one minced tissue particle derived from ligament or tendon tissue and including viable cells that can migrate from the tissue particle onto the scaffold. The biocompatible tissue implants can also include an additional biological agent and/or an optional retaining element placed over the minced tissue.

[0013] The tissue particle is preferably associated with a physiological buffering solution to form a suspension.

[0014] The implants may be made by providing at least one biocompatible scaffold and a sample of minced tissue, processing the tissue sample to create a suspension of viable tissue having at least one minced tissue fragment, and depositing the tissue sample upon the biocompatible scaffold.

[0015] In embodiments in which the implant is used for tissue repair, the tissue repair implant can be used to treat a variety of injuries, such as for example, injuries occurring within the musculoskeletal system, such as rotator cuff injuries, ACL ruptures, or meniscal tears, as well as injuries occurring in other connective tissues, such as skin and cartilage. Furthermore, such implants can be used in other orthopaedic surgical procedures, such as hand and foot surgery, to repair tissues such as ligaments, nerves, and tendons.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention will be more fully understood by reference to the following detailed description when considered in conjunction with the accompanying drawings, in which:

FIG. 1A is photomicrograph that demonstrates that cells in a cartilage tissue sample migrate extensively into a polymer scaffold;

FIG. 1B is a photomicrograph that demonstrates that the migrating cells of FIG. 1A retain their phenotype and the migrating cells produce cellular matrix that stains positive for sulfated glycosaminoglycan using the Safranin O stain;

FIG. 2A is a photomicrograph that demonstrates that cells within the minced tissue loaded on the biocompatible scaffolds, following implantation into SCID mice, have proliferated and filled the entire scaffold;

FIG. 2B is a photomicrograph that demonstrates that cells within the minced tissue, following implantation into SCID mice, are chondrocyte-like and are surrounded by an abundant matrix that stains positive for Safranin O;

FIG. 3A is a photomicrograph that illustrates a scaffold loaded with minced tissue;

FIG. 3B is a photomicrograph that illustrates a scaffold loaded with minced tissue and platelet rich plasma (PRP) and demonstrates that growth factors in the PRP are beneficial in promoting the migration of chondrocyte cells from the minced tissue and in promoting maintenance of differentiated phenotype of the chondrocyte cells within the scaffolds;

FIG. 4 is a photomicrograph that demonstrates that autologous cell dispersion (derived from skin) is present histologically as keratinocyte islands;

FIG. 5A is a photomicrograph that demonstrates the extensive migration of cells into the polymer scaffolds after incubating for 6 weeks in culture the biocompatible scaffolds having minced anterior cruciate tissue fragments that have been treated with collagenase;

FIG. 5B is a photomicrograph that demonstrates the extensive migration of cells into the polymer scaffolds after incubating for 6 weeks in culture the biocompatible scaffolds having minced anterior cruciate tissue fragments treated without collagenase;

FIG. 6A is a graph that demonstrates that cells in a meniscal explant sample migrate extensively into a polymer scaffold;

FIG. 6B is a photomicrograph that illustrates the histology of cross sections of the associated meniscal explant and biocompatible scaffolds, which demonstrates that cells in the meniscal explant sample migrate into the polymer scaffold.

FIGS. 7A - 7C are photomicrographs of histological sections of explant samples obtained following the procedure of Example 7, demonstrating the distribution and nature of tissue formed within a scaffold and grown from minced cartilage tissue fragments.

FIGS. 8A - 8C are photomicrographs of histological sections of explant samples obtained following the procedure of Example 7, demonstrating the distribution and nature of tissue formed within a scaffold and grown from bone cartilage paste.

FIG. 9 is a graph comparing the numbers of cells obtained for different sizes of minced cartilage tissue fragments.

FIGS. 10A - 10C are photomicrographs of histological sections of explant samples obtained following the procedure of Example 8, demonstrating the uniformity of the cartilage-like tissue obtained with minced cartilage tissue fragments of different sizes.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The biocompatible tissue implants of the present invention are used in the treatment of various types of tissue for various purposes. For example, the implants can be used for the repair and/or regeneration of diseased or damaged tissue, or they can be used for tissue bulking, tissue augmentation, cosmetic treatments, therapeutic treatments, and for tissue sealing. The tissue implants include a biocompatible scaffold and a minced tissue having at least one minced tissue fragment, wherein the minced tissue is associated with the scaffold. The minced tissue includes at least one viable cell that can migrate from the tissue fragment and onto the scaffold.

[0018] Although the implants are sometimes referred to herein as "tissue repair implants" and the methods of

using the implants are sometimes characterized as tissue repair techniques. it is understood that the Implants can be used for a variety of tissue treatments, including but not limited to tissue repair, tissue bulking, cosmetic treatments, therapeutic treatments, tissue augmentation, and tissue sealing.

[0019] The biocompatible tissue implant of the present invention includes a biocompatible scaffold having at least a portion in contact with the minced tissue suspension. The minced tissue suspension can be disposed on the outer surface of the scaffold, on an inner region of the scaffold, and any combination thereof, or alternatively, the entire scaffold can be in contact with the minced tissue suspension. The scaffold can be formed using virtually any material or delivery vehicle that is biocompatible. bioimplantable, easily sterilized and that has sufficient structural integrity and physical and/or mechanical properties to effectively provide for ease of handling in an operating room environment and to permit it to accept and retain sutures or other fasteners without substantially tearing. Alternatively, the scaffold could be in the form of an injectable gel that would set in place at the defect site. Sufficient strength and physical properties are developed in the scaffold through the selection of materials used to form the scaffold, and the manufacturing process. Preferably, the scaffold is also pliable so as to allow the scaffold to adjust to the dimensions of the target site of implantation. In some embodiments, the scaffold can be a bioresorbable or bioabsorbable material.

[0020] In one embodiment of the present invention, the scaffold can be formed from a biocompatible polymer. A variety of biocompatible polymers can be used to make the biocompatible tissue implants or scaffold devices according to the present invention. The biocompatible polymers can be synthetic polymers, natural polymers or combinations thereof. As used herein the term "synthetic polymer" refers to polymers that are not found in nature, even if the polymers are made from naturally occurring biomaterials. The term "natural polymer" refers to polymers that are naturally occurring. In embodiments where the scaffold includes at least one synthetic polymer, suitable biocompatible synthetic polymers can include polymers selected from the group consisting of aliphatic polyesters, poly(amino acids), copoly(ether-esters), polyalkylenes oxalates, polyamides, tyrosine derived polycarbonates, poly(iminocarbonates), polyorthoesters, polyoxaesters, polyamidoesters, polyoxaesters containing amine groups, poly(anhydrides), polyphosphazenes, and blends thereof. Suitable synthetic polymers for use in the present invention can also include biosynthetic polymers based on sequences found in collagen, elastin, thrombin, fibronectin, starches, poly(amino acid), poly (propylene fumarate), gelatin, alginate, pectin, fibrin, oxidized cellulose, chitin, chitosan, tropoelastin, hyaluronic acid, ribonucleic acids, deoxyribonucleic acids, polypeptides, proteins, polysaccharides, polynucleotides and combinations thereof.

[0021] For the purpose of this invention aliphatic polyesters include, but are not limited to, homopolymers and copolymers of lactide (which includes lactic acid, D-,L- and meso lactide); glycolide (including glycolic acid); ε-caprolactone; p-dioxanone (1,4-dioxan-2-one); trimethylene carbonate (1,3-dioxan-2-one); alkyl derivatives of trimethylene carbonate; δ-valerolactone; β-butyrolactone; γ-butyrolactone; ε-decalactone; hydroxybutyrate; hydroxyvalerate; 1,4-dioxepan-2-one (including its dimer 1,5,8,12-tetraoxacyclotetradecane-7,14-dione); 1,5-dioxepan-2-one; 6,6-dimethyl-1,4-dioxan-2-one; 2,5-diketomorpholine: pivalolactone; α, α diethylpropiolactone; ethylene carbonate: ethylene oxalate; 3-methyl-1,4-dioxane-2,5-dione; 3,3-diethyl-1,4-dioxan-2,5-dione; 6,6-dimethyl-dioxepan-2-one; 6,8-dioxabicycloctane-7-one and polymer blends thereof. Aliphatic polyesters used in the present invention can be homopolymers or copolymers (random, block, segmented, tapered blocks, graft, triblock, etc.) having a linear, branched or star structure. Poly(iminocarbonates), for the purpose of this invention, are understood to include those polymers as described by Kemnitzer and Kohn, in the Handbook of Biodegradable Polymers, edited by Domb, et. al., Hardwood Academic Press, pp. 251-272 (1997). Copoly(ether-esters), for the purpose of this invention, are understood to include those copolyester-ethers as described in the Journal of Biomaterials Research, Vol. 22, pages 993-1009, 1988 by Cohn and Younes, and in Polymer Preprints (ACS Division of Polymer Chemistry), Vol. 30(1), page 498, 1989 by Cohn (e.g., PEO/PLA). Polyalkylene oxalates, for the purpose of this invention, include those described in U.S. Patent Numbers 4,208,511; 4,141,087; 4,130,639; 4,140,678; 4.105,034; and 4,205,399. Polyphosphazenes, co-, ter- and higher order mixed monomer based polymers made from L-lactide, D,L-lactide, lactic acid, glycolide, glycolic acid, para-dioxanone, trimethylene carbonate and ε-caprolactone such as are described by Allcock in The Encyclopedia of Polymer Science, Vol. 13, pages 31-41, Wiley Interscience, John Wiley & Sons, 1988 and by Vandorpe, et al in the Handbook of Biodegradable Polymers, edited by Domb, et al., Hardwood Academic Press, pp. 161-182 (1997). Polyanhydrides include those derived from diacids of the form $HOOC\text{-}C_6H_4\text{-}O\text{-}(CH_2)_m\text{-}O\text{-}C_6H_4\text{-}COOH$, where "m" is an integer in the range of from 2 to 8, and copolymers thereof with aliphatic alpha-omega diacids of up to 12 carbons. Polyoxaesters, polyoxaamides and polyoxaesters containing amines and/or amido groups are described in one or more of the following U.S. Patent Nos. 5,464,929; 5,595,751; 5,597,579; 5,607,687; 5,618,552; 5,620,698; 5,645,850; 5,648,088; 5,698,213; 5,700,583; and 5,859,150. Polyorthoesters such as those described by Heller in Handbook of Biodegradable Polymers, edited by Domb, et al., Hardwood Academic Press, pp. 99-118 (1997).

[0022] As used herein, the term "glycolide" is understood to include polyglycolic acid. Further, the term "lactide" is understood to include L-lactide, D-lactide, blends thereof, and lactic acid polymers and copolymers.

[0023] Elastomeric copolymers are also particularly useful in the present invention. Suitable elastomeric polymers include those with an inherent viscosity in the range of 1.2 dL/g to 4 dL/g, more preferably 1.2 dL/g to 2 dL/g and most preferably 1.4 dL/g to 2 dL/g as determined at 25°C in a 0.1 gram per deciliter (g/dL) solution of polymer in hexafluoroisopropanol (HFIP). Further, suitable elastomers exhibit a high percent elongation and a low modulus, while possessing good tensile strength and good recovery characteristics. In the preferred embodiments of this invention, the elastomer exhibits a percent elongation greater than 200 percent and preferably greater than 500 percent. In addition to these elongation and modulus properties, suitable elastomers should also have a tensile strength greater than 3.45 MPa (500 psi), preferably greater than 6.89 MPa (1,000 psi), and a tear strength of greater than 345 kPa (50 lbs/inch), preferably greater than 552 kPa (80 lbs/inch).

[0024] Exemplary biocompatible elastomers that can be used in the present invention include, but are not limited to, elastomeric copolymers ε-caprolactone and glycolide (including polyglycolic acid) with a mole ratio of ε-caprolactone to glycolide of from 35:65 to 65:35, more preferably from 45:55 to 35:65; elastomeric copolymers of ε-caprolactone and lactide (including L-lactide, D-lactide, blends thereof, and lactic acid polymers and copolymers) where the mole ratio of ε-caprolactone to lactide is from 35:65 to 65:35 and more preferably from 45:55 to 30:70 or from 95:5 to 85:15; elastomeric copolymers of p-dioxanone (1,4-dioxan-2-one) and lactide (including L-lactide, D-lactide, blends thereof, and lactic acid polymers and copolymers) where the mole ratio of p-dioxanone to lactide is from 40:60 to 60:40; elastomeric copolymers of ε-caprolactone and p-dioxanone where the mole ratio of ε-caprolactone to p-dioxanone is from from 30:70 to 70:30; elastomeric copolymers of p-dioxanone and trimethylene carbonate where the mole ratio of p-dioxanone to trimethylene carbonate is from 30:70 to 70:30; elastomeric copolymers of trimethylene carbonate and glycolide (including polyglycolic acid) where the mole ratio of trimethylene carbonate to glycolide is from 30:70 to 70:30; elastomeric copolymers of trimethylene carbonate and lactide (including L-lactide, D-lactide, blends thereof, and lactic acid polymers and copolymers) where the mole ratio of trimethylene carbonate to lactide is from 30:70 to 70:30; and blends thereof. Examples of suitable biocompatible elastomers are described in U.S. Patent Nos. 4,045,418; 4,057,537 and 5,468,253.

[0025] In one embodiment, the elastomer is a copolymer of 35:65 ε-caprolactone and glycolide, formed in a dioxane solvent and including a polydioxanone mesh. In another embodiment, the elastomer is a copolymer of 40:60 ε-caprolactone and lactide with a polydioxanone mesh. In yet another embodiment, the elastomer is a 50:50 blend of a 35:65 copolymer of ε-caprolactone and glycolide and 40:60 copolymer of ε-caprolactone and lactide. The polydioxanone mesh may be in the form of a one layer thick two-dimensional mesh or a multi-layer thick three-dimensional mesh.

[0026] The scaffold of the present invention can, optionally, be formed from a bioresorbable or bioabsorbable material that has the ability to resorb in a timely fashion in the body environment. The differences in the absorption time under *in vivo* conditions can also be the basis for combining two different copolymers when forming the scaffolds of the present invention. For example, a copolymer of 35:65 ε-caprolactone and glycolide (a relatively fast absorbing polymer) can be blended with 40:60 ε-caprolactone and L-lactide copolymer (a relatively slow absorbing polymer) to form a biocompatible scaffold. Depending upon the processing technique used, the two constituents can be either randomly inter-connected bicontinuous phases, or the constituents could have a gradient-like architecture in the form of a laminate type composite with a well integrated interface between the two constituent layers. The microstructure of these scaffolds can be optimized to regenerate or repair the desired anatomical features of the tissue that is being regrown.

[0027] In one embodiment, it is desirable to use polymer blends to form scaffolds which transition from one composition to another composition in a gradient-like architecture. Scaffolds having this gradient-like architecture are particularly advantageous in tissue engineering applications to repair or regenerate the structure of naturally occurring tissue such as cartilage (articular, meniscal, septal, tracheal, auricular, costal, etc.), tendon, ligament, nerve, esophagus, skin, bone, and vascular tissue. For example, by blending an elastomer of ε-caprolactone-co-glycolide with ε-caprolactone-co-lactide (e.g., with a mole ratio of about 5:95) a scaffold may be formed that transitions from a softer spongy material to a stiffer more rigid material, for example, in a manner similar to the transition from cartilage to bone. Clearly, one of ordinary skill in the art will appreciate that other polymer blends may be used for similar gradient effects, or to provide different gradients (e.g., different absorption profiles, stress response profiles, or different degrees of elasticity). For example, such design features can establish a concentration gradient for the suspension of minced tissue associated with the scaffolds of the present invention, such that a higher concentration of the tissue fragments is present in one region of the implant (e.g., an interior portion) than in another region (e.g., outer portions).

[0028] The biocompatible scaffold of the tissue repair implant of the present invention can also include a reinforcing material comprised of any absorbable or non-absorbable textile having, for example, woven, knitted, warped knitted (i.e., lace-like), non-woven, and braided structures. In one embodiment, the reinforcing material has a mesh-like structure. In any of the above structures, mechanical properties of the material can be altered by changing the density or texture of the material, the type of knit or weave of the material, the thickness of the material, or by embedding particles in the material. The mechanical properties of the material may also be altered

by creating sites within the mesh where the fibers are physically bonded with each other or physically bonded with another agent, such as, for example, an adhesive or a polymer. The fibers used to make the reinforcing component can be monofilaments, yarns, threads, braids, or bundles of fibers. These fibers can be made of any biocompatible material including bioabsorbable materials such as polylactic acid (PLA), polyglycolic acid (PGA), polycaprolactone (PCL), polydioxanone (PDO), trimethylene carbonate (TMC), copolymers or blends thereof. These fibers can also be made from any biocompatible materials based on natural polymers including silk and collagen-based materials. These fibers can also be made of any biocompatible fiber that is nonresorbable, such as, for example, polyethylene, polyethylene terephthalate, poly(tetrafluoroethylene), polycarbonate, polypropylene and poly(vinyl alcohol). In one embodiment, the fibers are formed from 95:5 copolymer of lactide and glycolide.

[0029] In another embodiment, the fibers that form the reinforcing material can be made of a bioabsorbable glass. Bioglass, a silicate containing calcium phosphate glass, or calcium phosphate glass with varying amounts of solid particles added to control resorption time are examples of materials that could be spun into glass fibers and used for the reinforcing material. Suitable solid particles that may be added include iron, magnesium, sodium, potasslum, and combinations thereof.

[0030] The biocompatible scaffolds as well as the reinforcing material may also be formed from a thin, perforation-containing elastomeric sheet with pores or perforations to allow tissue ingrowth. Such a sheet could be made of blends or copolymers of polylactic acid (PLA), polyglycolic acid (PGA), polycaprolactone (PCL), and polydioxanone (PDO).

[0031] In one embodiment, filaments that form the biocompatible scaffolds or the reinforcing material may be co-extruded to produce a filament with a sheath/core construction. Such filaments are comprised of a sheath of biodegradable polymer that surrounds one or more cores comprised of another biodegradable polymer. Filaments with a fast-absorbing sheath surrounding a slower-absorbing core may be desirable in instances where extended support is necessary for tissue ingrowth.

[0032] One of ordinary skill in the art will appreciate that one or more layers of the reinforcing material may be used to reinforce the tissue implant of the invention. In addition, biodegradable textile scaffolds, such as, for example, meshes, of the same structure and chemistry or different structures and chemistries can be overlaid on top of one another to fabricate biocompatible tissue implants with superior mechanical strength.

[0033] In embodiments where the scaffold includes at least one natural polymer, suitable examples of natural polymers include, but are not limited to, fibrin-based materials, collagen-based materials, hyaluronic acid-based materials, glycoprotein-based materials, cellulose-based materials, silks and combinations thereof. By way of nonlimiting example, the biocompatible scaffold can be constructed from a collagen-based small intestine submucosa.

[0034] In another embodiment of the present invention, the biocompatible scaffold can be formed from a biocompatible ceramic material. Suitable biocompatible ceramic materials include, for example, hydroxyapatite, α-tricalcium phosphate, β-tricalcium phosphate, bioactive glass, calcium phosphate, calcium sulfate, calcium carbonate, xenogeneic and allogeneic bone material and combinations thereof. Suitable bioactive glass materials for use in the present invention include silicates containing calcium phosphate glass, or calcium phosphate glass with varying amounts of solid particles added to control resorption time. Suitable compounds that may be incorporated into the calcium phosphate bioactive glass include, but are not limited to, magnesium oxide, sodium oxide, potassium oxide, and combinations thereof.

[0035] In yet another embodiment of the tissue implants of the present invention, the scaffold can be formed using tissue grafts, such as may be obtained from autogeneic tissue, allogeneic tissue and xenogeneic tissue. By way of non-limiting example, tissues such as skin, cartilage, ligament, tendon, periosteum, perichondrium, synovium, fascia, mesenter and sinew can be used as tissue grafts to form the biocompatible scaffold. In some embodiments where an allogeneic tissue is used, tissue from a fetus or newborns can be used to avoid the immunogenicity associated with some adult tissues.

[0036] In another embodiment, the scaffold could be in the form of an injectable gel that would set in place at the defect site. The gel can be a biological or synthetic hydrogel, including alginate, cross-linked alginate, hyaluronic acid, collagen gel, fibrin glue, fibrin clot, poly(N-isopropylacrylamide), agarose, chitin, chitosan, cellulose, polysaccharides, poly(oxyalkylene), a copolymer of poly(ethylene oxide)-poly(propylene oxide), poly(vinyl alcohol), polyacrylate, platelet rich plasma (PRP) clot, platelet poor plasma (PPP) clot, Matrigel, or blends thereof.

[0037] In still yet another embodiment of the tissue implants, the scaffold can be formed from a polymeric foam component having pores with an open cell pore structure. The pore size can vary, but preferably, the pores are sized to allow tissue ingrowth. More preferably, the pore size is in the range of 50 to 1000 microns, and even more preferably, in the range of 50 to 500 microns. The polymeric foam component can, optionally, contain a reinforcing component, such as for example, the textiles disclosed above. In some embodiments where the polymeric foam component contains a reinforcing component, the foam component can be integrated with the reinforcing component such that the pores of the foam component penetrate the mesh of the reinforcing component and interlock with the reinforcing component.

[0038] The foam component of the tissue implant may be formed as a foam by a variety of techniques well known to those having ordinary skill in the art. For example, the

polymeric starting materials may be foamed by lyophilization, supercritical solvent foaming (i.e., as described in EP 464,163), gas injection extrusion, gas injection molding or casting with an extractable material (e.g., salts, sugar or similar suitable materials).

[0039] In one embodiment, the foam component of the engineered tissue repair implant devices of the present invention may be made by a polymer-solvent phase separation technique, such as lyophilization. Generally, however, a polymer solution can be separated into two phases by any one of the four techniques: (a) thermally induced gelation/crystallization; (b) non-solvent induced separation of solvent and polymer phases; (c) chemically induced phase separation, and (d) thermally induced spinodal decomposition. The polymer solution is separated in a controlled manner into either two distinct phases or two bicontinuous phases. Subsequent removal of the solvent phase usually leaves a porous structure with a density less than the bulk polymer and pores in the micrometer ranges. See Microcellular Foams Via Phase Separation, J. Vac. Sci. Technol., A. T. Young, Vol. 4(3), May/Jun 1986.

[0040] The steps involved in the preparation of these foams include choosing the right solvents for the polymers to be lyophilized and preparing a homogeneous solution. Next, the polymer solution is subjected to a freezing and vacuum drying cycle. The freezing step phase separates the polymer solution and vacuum drying step removes the solvent by sublimation and/or drying, leaving a porous polymer structure or an interconnected open cell porous foam.

[0041] Suitable solvents that may be used in the preparation of the foam component include, but are not limited to, formic acid, ethyl formate, acetic acid, hexafluoroisopropanol (HFIP), cyclic ethers (e.g., tetrahydrofuran (THF), dimethylene fluoride (DMF), and polydioxanone (PDO)), acetone, acetates of C2 to C5 alcohols (e.g., ethyl acetate and t-butylacetate), glyme (e.g., monoglyme, ethyl glyme, diglyme, ethyl diglyme, triglyme, butyl diglyme and tetraglyme), methylethyl ketone, dipropyleneglycol methyl ether, lactones (e.g., γ-valerolactone, δ-valerolactone, β-butyrolactone, γ-butyrolactone), 1,4-dioxane, 1,3-dioxolane, 1,3-dioxolane-2-one (ethylene carbonate), dimethlycarbonate, benzene, toluene, benzyl alcohol, p-xylene, naphthalene, tetrahydrofuran, N-methyl pyrrolidone, dimethylformamide, chloroform, 1,2-dichloromethane, morpholine, dimethylsulfoxide, hexafluoroacetone sesquihydrate (HFAS), anisole and mixtures thereof. Among these solvents, a preferred solvent is 1,4-dioxane. A homogeneous solution of the polymer in the solvent is prepared using standard techniques.

[0042] The applicable polymer concentration or amount of solvent that may be utilized will vary with each system. Generally, the amount of polymer in the solution can vary from 0.5% to 90% and, preferably, will vary from 0.5% to 30% by weight, depending on factors such as the solubility of the polymer in a given solvent and the final properties desired in the foam.

[0043] In one embodiment, solids may be added to the polymer-solvent system to modify the composition of the resulting foam surfaces. As the added particles settle out of solution to the bottom surface, regions will be created that will have the composition of the added solids, not the foamed polymeric material. Alternatively, the added solids may be more concentrated in desired regions (i.e., near the top, sides, or bottom) of the resulting tissue implant, thus causing compositional changes in all such regions. For example, concentration of solids in selected locations can be accomplished by adding metallic solids to a solution placed in a mold made of a magnetic material (or vice versa).

[0044] A variety of types of solids can be added to the polymer-solvent system. Preferably, the solids are of a type that will not react with the polymer or the solvent. Generally, the added solids have an average diameter of less than 1.0 mm and preferably will have an average diameter of 50 to 500 microns. Preferably, the solids are present in an amount such that they will constitute from 1 to 50 volume percent of the total volume of the particle and polymer-solvent mixture (wherein the total volume percent equals 100 volume percent).

[0045] Exemplary solids include, but are not limited to, particles of demineralized bone, calcium phosphate particles, bioglass particles, calcium sulfate, or calcium carbonate particles for bone repair, leachable solids for pore creation and particles of bioabsorbable polymers not soluble in the solvent system that are effective as reinforcing materials or to create pores as they are absorbed, and non-bioabsorbable materials.

[0046] Suitable leachable solids include nontoxic leachable materials such as salts (e.g., sodium chloride, potassium chloride, calcium chloride, sodium tartrate, sodium citrate, and the like), biocompatible mono and disaccharides (e.g., glucose, fructose, dextrose, maltose, lactose and sucrose), polysaccharides (e.g., starch, alginate, chitosan), water soluble proteins (e.g., gelatin and agarose). The leachable materials can be removed by immersing the foam with the leachable material in a solvent in which the particle is soluble for a sufficient amount of time to allow leaching of substantially all of the particles, but which does not dissolve or detrimentally alter the foam. The preferred extraction solvent is water, most preferably distilled-deionized water. Such a process is described in U.S. Patent No. 5,514,378. Preferably the foam will be dried after the leaching process is complete at low temperature and/or vacuum to minimize hydrolysis of the foam unless accelerated absorption of the foam is desired.

[0047] Suitable non-bioabsorbable materials include biocompatible metals such as stainless steel, cobalt chrome, titanium and titanium alloys, and bioinert ceramic particles (e.g., alumina, zirconia, and calcium sulfate particles). Further, the non-bioabsorbable materials may include polymers such as polyethylene, polyvinylacetate, polymethylmethacrylate, polypropylene, poly(ethylene

terephthalate), silicone, polyethylene oxide, polyethylene glycol, polyurethanes, polyvinyl alcohol, natural polymers (e.g., cellulose particles, chitin, and keratin), and fluorinated polymers and copolymers (e.g., polyvinylidene fluoride, polytetrafluoroethylene, and hexafluoropropylene).

[0048] It is also possible to add solids (e.g., barium sulfate) that will render the tissue implants radio opaque. The solids that may be added also include those that will promote tissue regeneration or regrowth, as well as those that act as buffers, reinforcing materials or porosity modifiers.

[0049] As noted above, porous, reinforced tissue repair implant devices of the present invention are made by injecting, pouring, or otherwise placing, the appropriate polymer solution into a mold set-up comprised of a mold and the reinforcing elements of the present invention. The mold set-up is cooled in an appropriate bath or on a refrigerated shelf and then lyophilized, thereby providing a reinforced scaffold. A biological component can be added either before or after the lyophilization step. In the course of forming the foam component, it is believed to be important to control the rate of freezing of the polymer-solvent system. The type of pore morphology that is developed during the freezing step is a function of factors such as the solution thermodynamics, freezing rate, temperature to which it is cooled, concentration of the solution, and whether homogeneous or heterogenous nucleation occurs. One of ordinary skill in the art can readily optimize the parameters without undue experimentation.

[0050] The required general processing steps include the selection of the appropriate materials from which the polymeric foam and the reinforcing components are made. If a mesh reinforcing material is used, the proper mesh density must be selected. Further, the reinforcing material must be properly aligned in the mold, the polymer solution must be added at an appropriate rate and, preferably, into a mold that is tilted at an appropriate angle to avoid the formation of air bubbles, and the polymer solution must be lyophilized.

[0051] In embodiments that utilize a mesh reinforcing material, the reinforcing mesh has to be of a certain density. That is, the openings in the mesh material must be sufficiently small to render the construct sutureable or otherwise fastenable, but not so small as to impede proper bonding between the foam and the reinforcing mesh as the foam material and the open cells and cell walls thereof penetrate the mesh openings. Without proper bonding the integrity of the layered structure is compromised leaving the construct fragile and difficult to handle. Because the density of the mesh determines the mechanical strength of the construct, the density of the mesh can vary according to the desired use for tissue repair. In addition, the type of weave used in the mesh can determine the directionality of the mechanical strength of the construct, as well as the mechanical properties of the reinforcing material, such as for example, the elasticity, stiffness, burst strength, suture retention strength and ultimate tensile strength of the construct. By way of nonlimiting example, the mesh reinforcing material in a foam-based biocompatible scaffold of the present invention can be designed to be stiff in one direction, yet elastic in another, or alternatively, the mesh reinforcing material can be made isotropic.

[0052] During the lyophilization of the reinforced foam, several parameters and procedures are important to produce implants with the desired integrity and mechanical properties. Preferably, the reinforcement material is substantially flat when placed in the mold. To ensure the proper degree of flatness, the reinforcement (e.g., mesh) is pressed flat using a heated press prior to its placement within the mold. Further, in the event that reinforcing structures are not isotropic it is desirable to indicate this anisotropy by marking the construct to indicate directionality. This can be accomplished by embedding one or more indicators, such as dyed markings or dyed threads, within the woven reinforcements. The direction or orientation of the indicator will indicate to a surgeon the dimension of the implant in which physical properties are superior.

[0053] As noted above, the manner in which the polymer solution is added to the mold prior to lyophilization helps contribute to the creation of a tissue implant with adequate mechanical integrity. Assuming that a mesh reinforcing material will be used, and that it will be positioned between two thin (e.g., 0.75 mm) shims it should be positioned in a substantially flat orientation at a desired depth in the mold. The polymer solution is poured in a way that allows air bubbles to escape from between the layers of the foam component. Preferably, the mold is tilted at a desired angle and pouring is effected at a controlled rate to best prevent bubble formation. One of ordinary skill in the art will appreciate that a number of variables will control the tilt angle and pour rate. Generally, the mold should be tilted at an angle of greater than about 1 degree to avoid bubble formation. In addition, the rate of pouring should be slow enough to enable any air bubbles to escape from the mold, rather than to be trapped in the mold.

[0054] If a mesh material is used as the reinforcing component, the density of the mesh openings is an important factor in the formation of a resulting tissue implant with the desired mechanical properties. A low density, or open knitted mesh material, is preferred. One preferred material is a 90:10 copolymer of glycolide and lactide, sold under the tradename VICRYL (Ethicon, Inc., Somerville, NJ). One exemplary low density, open knitted mesh is Knitted VICRYL VKM-M, available from Ethicon, Inc., Somerville, NJ. Other preferred materials are polydioxanone or 95:5 copolymer of lactide and glycolide.

[0055] The density or "openness" of a mesh material can be evaluated using a digital photocamera interfaced with a computer. In one evaluation, the density of the mesh was determined using a Nikon SMZ-U Zoom with a Sony digital photocamera DKC-5000 interfaced with

an IBM 300PL computer. Digital images of sections of each mesh magnified to 20x were manipulated using Image-Pro Plus 4.0 software in order to determine the mesh density. Once a digital image was captured by the software, the image was thresholded such that the area accounting for the empty spaces in the mesh could be subtracted from the total area of the image. The mesh density was taken to be the percentage of the remaining digital image. Implants with the most desirable mechanical properties were found to be those with a mesh density in the range of 12 to 80 % and more preferably 45 to 80%.

[0056] In one embodiment, the preferred scaffold for cartilage repair is a mesh reinforced foam. More preferably, the foam is reinforced with a mesh that includes polydioxanone (PDO) and the foam composition is a copolymer of 35:65 ε-caprolactone and glycolide. For articular cartilage, the preferred structure to allow cell and tissue ingrowth is one that has an open pore structure and is sized to sufficiently allow cell migration. A suitable pore size is one in which an average diameter is in the range of 50 to 1000 microns, and more preferably, between 50 to 500 microns. The mesh layer has a thickness in the range of 1 micron to 1000 microns. Preferably, the foam has a thickness in the range of 300 microns to 2 mm, and more preferably, between 500 microns and 1.5 mm. Preferably, the mesh layer has a mesh density in the range of 12 to 80 % and more preferably 45 to 80%.

[0057] In another embodiment, the preferred scaffold for cartilage repair is a nonwoven structure. More preferably, the composition of the nonwoven structure are PANACRYL, a 95:5 copolymer of lactide and glycolide, VICRYL, a 90:10 copolymer of glycolide and lactide, or a blend of polydioxanone and VICRYL sold under the tradename ETHISORB (Johnson & Johnson International, Belgium). For articular cartilage, the preferred structure to allow cell and tissue ingrowth is one that has an open pore structure and is sized to sufficiently allow cell migration. A suitable pore size for the nonwoven scaffold is one in which an average diameter is in the range of 50 to 1000 microns and more preferably between 100 to 500 microns. The nonwoven scaffold has a thickness between 300 microns and 2 mm, and more preferably, between 500 microns and 1.5 mm.

[0058] In one embodiment, the preferred scaffold for meniscus repair is a mesh reinforced foam. More preferably, the foam is reinforced foam with a mesh that includes polydioxanone (PDO) and the foam composition is a copolymer of 35:65 ε-caprolactone and glycolide. The preferred structure to allow cell and tissue ingrowth is one that has an open pore structure and is sized to sufficiently allow cell migration. A suitable pore size is one in which an average diameter is in the range of 50 to 1000 microns, and more preferably, between 50 to 500 microns. The mesh layer has a thickness in the range of 1 micron to 1000 microns. Preferably, the foam has a thickness in the range of 300 microns to 2 mm, and more preferably, between 500 microns and 1.5 mm. In this embodiment, the preferred method of use is to surround the minced cartilage tissue with this scaffold material. Preferably, the mesh layer has a mesh density in the range of 12 to 80 % and more preferably 45 to 80%.

[0059] In one embodiment, the preferred scaffold for tendon or ligament repair is a mesh reintorced foam. More preferably, the foam is reintorced with a mesh that includes polydioxanone (PDO) and the foam composition is a copolymer of 35:65 ε-caprolactone and glycolide. The preferred structure to allow cell and tissue ingrowth is one that has an open pore structure and is sized to sufficiently allow cell migration. A suitable pore size is one in which an average diameter is in the range of 50 to 1000 microns, and more preferably, between 50 to 500 microns. The mesh layer has a thickness in the range of 1 micron to 1000 microns. Preferably, the foam has a thickness in the range of 300 microns to 2 mm, and more preferably, between 500 microns and 1.5 mm. Preferably, the mesh layer has a mesh density in the range of 12 to 80% and more preferably 45 to 80%.

[0060] In another embodiment, the preferred scaffold for tendon or ligament repair is constructed from a polymer that has a slow resorption profile (e.g., at least three months, and preferably, at least six months) and high mechanical strength. More preferably, the tensile strength and elastic modulus ot the scaffold must be similar to that of native ligament. The preferred tensile strength of the scaffold is between 500N and 4000N, and more preferably, between 1000N and 2500N. The preferred elastic modulus of the scaffold is between 100N/m and 300N/m, and more preferably, between 150N/m and 200N/m. The preferred structure of this scaffold is a cylindrical-shaped or elliptically-shaped scaffold or a scaffold with a high aspect ratio (i.e., ratio of length to width). Preferably, the aspect ratio is greater than 1, and more preferably it is greater than 2 and less than 100. Further, the scaffold preferably has a diameter or width in the range of 3 mm and 12 mm, and more preferably, between 4 mm and 10 mm. By way of non-limiting exampie, the scaffold for ligament repair can include a 95:5 copolymer of lactide and glycolide. In one embodiment, the scaffold for ligament repair can be formed as a composite structure including a 95:5 copolymer of lactide and glycolide and other polymers, such as for example, polylactide, polyglycolide, polydioxanone, polycaprolactone and combinations thereof. The scaffold may be formed of a woven, knit or braided material. Optionally, the polymers from which the scaffold is made can be formed as a nonwoven, textile structure, such as for example, a weave or a mesh structure, or alternatively these polymers can be formed as a foam. In another embodiment, the composite structure can include natural polymers, such as for example, collagen, tibrin, or silk. In this embodiment, the natural polymer can act as a coating to the composite structure, or alternatively, the natural polymer can be formed as a foam. The composite structure can also optionally include strips of collagen or silk to reside within the whole scaffold or just the periphery of the scaffold.

[0061] In one embodiment, the scaffold useful for lig-

ament or tendon repair is formed of a plurality of filaments, a majority of the fibers of which are aligned in the longitudinal direction.

[0062] One of ordinary skill in the art will appreciate that the selection of a suitable material for forming the biocompatible scaffold of the present invention depends on several factors. These factors include *in vivo* mechanical performance; cell response to the material in terms of cell attachment, proliferation, migration and differentiation; biocompatibility; and optionally, bioabsorption (or bio-degradation) kinetics. Other relevant factors include the chemical composition, spatial distribution of the constituents, the molecular weight of the polymer, and the degree of crystallinity.

[0063] In addition to the biocompatible scaffold, the tissue repair implants of the present invention further include at least one sample of viable tissue that is associated with at least a portion of the scaffold. The term "viable," as used herein, refers to a tissue sample having one or more viable cells. The tissue used is ligament tissue or tendon tissue. The tissue used to construct the tissue implant can be autogenic tissue, allogenic tissue, or xenogeneic tissue.

[0064] The tissue can be obtained using any of a variety of conventional techniques, such as for example, by biopsy or other surgical removal. Preferably, the tissue sample is obtained under aseptic conditions. Once a sample of living tissue has been obtained, the sample can then be processed under sterile conditions to create a suspension having at least one minced, or finely divided, tissue particle. The particle size of each tissue fragment can vary, for example, the tissue size can be in the range of 0.1 and 3 mm^3, in the range of 0.5 and 1 mm^3, in the range of 1 to 2 mm^3, or in the range of 2 to 3 mm^3, but preferably the tissue particle is less than 1 mm^3.

[0065] The minced tissue has at least one viable cell that can migrate from the tissue fragment onto the scaffold. More preferably, the tissue contains an effective amount of cells that can migrate from the tissue fragment and begin populating the scaffold. In an optional embodiment, the minced tissue fragments may be contacted with a matrix-digesting enzyme to facilitate cell migration out of the extracellular matrix surrounding the cells. The enzymes are used to increase the rate of cell migration out of the extracellular matrix and into the scaffold material. Suitable matrix-digesting enzymes that can be used in the present invention include, but are not limited to, collagenase, chondroitinase, trypsin, elastase, hyaluronidase, petidase, thermolysin and protease.

[0066] In one embodiment, the minced tissue particles can be formed as a suspension in which the tissue particles are associated with a physiological buffering solution. Suitable physiological buffering solutions include, but are not limited to, saline, phosphate buffer solution, Hank's balanced salts, Tris buffered saline, Hepes buffered saline and combinations thereof. In addition, the tissue can be minced in any standard cell culture medium known to those having ordinary skill in the art, either in the presence or absence of serum. Prior to depositing the suspension of minced tissue on the scaffold or at the site of tissue injury, the minced tissue suspension can be filtered and concentrated, such that only a small quantity of physiological buffering solution remains in the suspension to prevent the tissue particles from drying out, and the minced tissue particles can be directly applied to the scaffold or site of injury. Preferably, the minced tissue particles are loaded at a concentration in the range of 1 to 100 mg/cm^2, and more preferably in the range of 1 to 20 mg/cm^2.

[0067] The suspension of minced living tissue can be used to create a tissue repair implant according to the present invention by depositing the suspension of living tissue upon a biocompatible scaffold, such that the tissue and the scaffold become associated. Preferably, the tissue is associated with at least a portion of the scaffold. The tissue repair implant can be implanted in a subject immediately, or alternatively, the construct can be incubated under sterile conditions for a duration and under conditions that are effective to maintain the viability of the tissue sample. In embodiments where the construct is incubated, the incubation conditions can vary, but preferably, the construct is incubated for a duration in the range of 1 hour to 6 weeks, and more preferably between 1 week and 6 weeks, at a temperature in the range of 20 to 40 °C, and in an atmosphere containing between 5 and 10 % carbon dioxide (CO_2) and high humidity, e.g., approximately 100% humidity.

[0068] A kit can be used to assist in the preparation of the tissue repair implants of the present invention. According to the present invention, the kit includes a sterile container that houses one or more biocompatible scaffolds, a harvesting tool for collecting the living tissue sample from a subject, and one or more reagents for sustaining the viability of the tissue sample. Suitable reagents for sustaining the viability of the tissue sample include a physiological solution, such as for example, saline, phosphate buffering solution, Hank's balanced salts, standard cell culture medium, Dulbecco's modified Eagle's medium, ascorbic acid, HEPES, nonessential amino acid, L-proline, fetal bovine serum, autologous serum, and combinations thereof. The kit can also include a processing tool for dividing the tissue into minced tissue particles, or alternatively, the harvesting tool can be adapted to collect the tissue sample and to process the sample into finely divided tissue particles. The kit can, optionally, also include a delivery device for transferring the scaffold from the sterile container to a subject for implantation.

[0069] A biological component may, optionally, be incorporated within the tissue repair implants of the present invention. Preferably, the biological component is incorporated within, or coated on, the scaffolds disclosed above. In embodiments where the biological component is coated onto the scaffold, the biological component is preferably associated with at least a portion of the scaffold. By way of nonlimiting example, the biocompatible scaffold can include an adhesion agent for anchoring the

suspension of minced tissue fragments to the scaffold. Preferably, the adhesion agent is an anchoring agent, a cross-linking agent (i.e., chemical or physical), and combinations thereof.

[0070] Suitable anchoring agents include, but are not limited to, hyaluronic acid, fibrin glue, fibrin clot, collagen gel, alginate gel, gelatin-resorcin-formalin adhesive, mussel-based adhesive, dihydroxyphenylalanine (DOPA) based adhesive, chitosan, transglutaminase, poly(amino acid)-based adhesive, cellulose-based adhesive, polysaccharide-based adhesive, synthetic acrylate-based adhesives, platelet rich plasma (PRP), platelet poor plasma (PPP), clot of PRP, clot of PPP, Matrigel, Monostearoyl Glycerol co-Succinate (MGSA), Monostearoyl Glycerol co-Succinate/polyethylene glycol (MGSA/PEG) copolymers, laminin, elastin, proteoglycans, and combinations thereof.

[0071] Suitable cross-linking agents include, for example, divinyl sulfone (DVS), polyethylene glycol divinyl sulfone (VS-PEG-VS), hydroxyethyl methacrylate divinyl sulfone (HEMA-DIS-HEMA), formaldehyde, glutaraldehyde, aldehydes, isocyanates, alkyl and aryl halides, imidoesters, N-substituted maleimides, acylating compounds, carbodiimide, hydroxychloride, N-hydroxysuccinimide, light (e.g., blue light and UV light), pH, temperature, and combinations thereof.

[0072] The biological components used in the present invention can also be selected from among a variety of effectors that, when present at the site of injury, promote healing and/or regeneration of the affected tissue. In addition to being compounds or agents that actually promote or expedite healing, the effectors may also include compounds or agents that prevent infection (e.g., antimicrobial agents and antibiotics), compounds or agents that reduce inflammation (e.g., anti-inflammatory agents), compounds that prevent or minimize adhesion formation, such as oxidized regenerated cellulose (e.g., INTERCEED and Surgicel®, available from Ethicon, Inc.), hyaluronic acid, and compounds or agents that suppress the immune system (e.g., immunosuppressants).

[0073] By way of example, other types of effectors present within the implant of the present invention can include heterologous or autologous growth factors, proteins (including matrix proteins), peptides, antibodies, enzymes, platelets, glycoproteins, hormones, cytokines, glycosaminoglycans, nucleic acids, analgesics, viruses, virus particles, and cell types. It is understood that one or more effectors of the same or different functionality may be incorporated within the implant.

[0074] Examples of suitable effectors include the multitude of heterologous or autologous growth factors known to promote healing and/or regeneration of injured or damaged tissue. These growth factors can be incorporated directly into the biocompatible scaffold, or alternatively, the biocompatible scaffold can include a source of growth factors, such as for example, platelets. Exemplary growth factors include, but are not limited to, TGF-β, bone morphogenic protein, cartilage-derived morphogenic protein, fibroblast growth factor, platelet-derived growth factor, vascular endothelial cell-derived growth factor (VEGF), epidermal growth factor, insulin-like growth factor, hepatocyte growth factor, and fragments thereof. Suitable effectors likewise include the agonists and antagonists of the agents noted above. The growth factor can also include combinations of the growth factors listed above. In addition, the growth factor can be autologous growth factor that is supplied by platelets in the blood. In this case, the growth factor from platelets will be an undefined cocktail of various growth factors.

[0075] The proteins that may be present within the implant include proteins that are secreted from a cell or other biological source, such as for example, a platelet, which is housed within the implant, as well as those that are present within the implant in an isolated form. The isolated form of a protein typically is one that is 55% or greater in purity, i.e., isolated from other cellular proteins, molecules, debris, etc. More preferably, the isolated protein is one that is at least 65% pure, and most preferably one that is at least 75 to 95% pure. Notwithstanding the above, one of ordinary skill in the art will appreciate that proteins having a purity below 55% are still considered to be within the scope of this invention. As used herein, the term "protein" embraces glycoproteins, lipoproteins, proteoglycans, peptides, and fragments thereof. Examples of proteins useful as effectors include, but are not limited to, pleiotrophin, endothelin, tenascin, fibronectin, fibrinogen, vitronectin, V-CAM, I-CAM, N-CAM, selectin, cadherin, integrin, laminin, actin, myosin, collagen, microfilament, intermediate filament, antibody, elastin, fibrillin, and fragments thereof.

[0076] Glycosaminoglycans, highly charged polysaccharides which play a role in cellular adhesion, may also serve as effectors according to the present invention. Exemplary glycosaminoglycans useful as effectors include, but are not limited to, heparan sulfate, heparin, chondroitin sulfate, dermatan sulfate, keratan sulfate, hyaluronan (also known as hyaluronic acid), and combinations thereof.

[0077] The biocompatible scaffolds of the present invention can also have cells incorporated therein. Suitable cell types that can serve as effectors according to this invention include, but are not limited to, osteocytes, osteoblasts, osteoclasts, fibroblasts, stem cells, pluripotent cells, chondrocyte progenitors, chondrocytes, endothelial cells, macrophages, leukocytes, adipocytes, monocytes, plasma cells, mast cells, umbilical cord cells, stromal cells, mesenchymal stem cells, epithelial cells, myoblasts, tenocytes, ligament fibroblasts, neurons, and bone marrow cells. Cells typically have at their surface receptor molecules which are responsive to a cognate ligand (e.g., a stimulator). A stimulator is a ligand which when in contact with its cognate receptor induce the cell possessing the receptor to produce a specific biological action. For example, in response to a stimulator (or ligand) a cell may produce significant levels of secondary messengers, like Ca^{+2}, which then will have subsequent

effects upon cellular processes such as the phosphorylation of proteins, such as (keeping with our example) protein kinase C. In some instances, once a cell is stimulated with the proper stimulator, the cell secretes a cellular messenger usually in the form of a protein (including glycoproteins, proteoglycans, and lipoproteins). This cellular messenger can be an antibody (e.g., secreted from plasma cells), a hormone, (e.g., a paracrine, autocrine, or exocrine hormone), a cytokine, or natural or synthetic fragments thereof.

[0078] The tissue implants of the invention can also be used in gene therapy techniques in which nucleic acids, viruses, or virus particles deliver a gene of interest, which encodes at least one gene product of interest, to specific cells or cell types. Accordingly, the biological effector can be a nucleic acid (e.g., DNA, RNA, or an oligonucleotide), a virus, a virus particle, or a non-viral vector. The viruses and virus particles may be, or may be derived from, DNA or RNA viruses. The gene product of interest is preferably selected from the group consisting of proteins, polypeptides, interference ribonucleic acids (iRNA) and combinations thereof.

[0079] Once the applicable nucleic acids and/or viral agents (i.e., viruses or viral particles) are incorporated into the biocompatible scaffold of the tissue repair implant, the implant can then be implanted into a particular site to elicit a type of biological response. The nucleic acid or viral agent can then be taken up by the cells and any proteins that they encode can be produced locally by the cells. In one embodiment, the nucleic acid or viral agent can be taken up by the cells within the tissue fragment of the minced tissue suspension, or, in an alternative embodiment, the nucleic acid or viral agent can be taken up by the cells in the tissue surrounding the site of the injured tissue. One of ordinary skill in the art will recognize that the protein produced can be a protein of the type noted above, or a similar protein that facilitates an enhanced capacity of the tissue to heal an injury or a disease, combat an infection, or reduce an inflammatory response. Nucleic acids can also be used to block the expression of unwanted gene product that may impact negatively on a tissue repair process or other normal biological processes. DNA, RNA and viral agents are often used to accomplish such an expression blocking function, which is also known as gene expression knock out.

[0080] One of ordinary skill in the art will appreciate that the identity of the biological component may be determined by a surgeon, based on principles of medical science and the applicable treatment objectives.

[0081] The biological component or effector of the issue repair implant can be incorporated within the scaffold before or after manufacture of the scaffold, or before or after the surgical placement of the implant. Prior to surgical placement, the biocompatible scaffold can be placed in a suitable container comprising the biological component. After an appropriate time and under suitable conditions, the scaffold will become impregnated with the biological component. Alternatively, the biological component can be incorporated within the scaffold by, for example, using an appropriately gauged syringe to inject the biological agent(s) into the scaffold. Other methods well known to those of ordinary skill in the art can be applied in order to load a scaffold with an appropriate biological component, such as mixing, pressing, spreading, centrifuging and placing the biological component into the scaffold. Alternatively, the biological component can be mixed with a gel-like carrier prior to injection into the scaffold. The gel-like carrier can be a biological or synthetic hydrogel, including an alginate, a cross-linked alginate, hyaluronic acid, collagen gel, poly(N-isopropylacrylamide), poly(oxyalkylene), a copolymer of poly(ethylene oxide)-poly(propylene oxide), poly(vinyl alcohol) and blends thereof.

[0082] Following surgical placement, an implant wherein the biocompatible scaffold is devoid of any biological component can be infused with biological agent (s), or an implant wherein the scaffold includes at least one biological component can be augmented with a supplemental quantity of the biological component. One method of incorporating a biological component within a surgically installed implant is by injection using an appropriately gauged syringe.

[0083] The amount of the biological component included with a biocompatible scaffold will vary depending on a variety of factors, including the size of the scaffold, the material from which the scaffold is made, the porosity of the scaffold, the identity of the biologically component, and the intended purpose of the tissue repair implant. One of ordinary skill in the art can readily determine the appropriate quantity of biological component to include within a biocompatible scaffold for a given application in order to facilitate and/or expedite the healing of tissue. The amount of biological component will, of course, vary depending upon the identity of the biological component and the given application. In another embodiment, the tissue repair implant can include an additional retaining element that is placed over the tissue-laden scaffold. Preferably, in this embodiment, at least a portion of the tissue suspension is associated with at least a portion of the outer surface of the scaffold, such that the tissue suspension is "sandwiched" between the biocompatible scaffold and the retaining element. The retaining element can be formed from virtually any biocompatible material, and in one embodiment, the retaining element can be formed using tissue grafts, including grafts obtained from allogeneic tissue, autogeneic tissue, and xenogeneic tissue, an additional biocompatible scaffold selected from the biocompatible scaffolds disclosed above, and combinations thereof. In another embodiment, the retaining element can be a porous mesh, a porous mesh-like material, such as for example, a knit, a weave, a nonwoven, or a thin, perforated elastomeric sheet having pores or perforations to allow tissue ingrowth. The thin, perforated elastomeric sheets are preferably constructed from collagen or silk or blends or copolymers of polylactic acid (PLA), polyglycolic acid (PGA), polycaprolactone (PCL)

and polydioxanone (PDO). The type of retaining element used can vary according to the desired tissue repair. By way of non-limiting example, in one embodiment for meniscus repair, the retaining element can be a mesh-reinforced foam. In embodiments for ACL and cartilage repair, the retaining element can be a mesh structure. In embodiments where the retaining element is an allograft or an autograft, preferably the allograft or autograft is selected from periosteum, perichondrium, iliotibial band or fascia lata, gracilis tendon, semitendinosis tendon, patellar tendon, synovium and combinations thereof. In embodiments where the retaining element is a xenograft, the xenograft is preferably selected from the corresponding anatomical structure for small intestine, periosteum, perichondrium, iliotibial band or fascia lata, gracilis tendon, semitendonous tendon, patellar tendon, synovium, and combinations thereof. These retaining elements can be placed over the biocompatible scaffold, or alternatively, the retaining element can be affixed, such as for example, by suturing or stapling, the implant to act as a retaining element. One of ordinary skill in the art will appreciate that additional processing of the retaining element, such as for example, the placement of holes within the retaining element, may be determined by a surgeon, based on principles of medical science and the applicable treatment objectives.

[0084] In yet another embodiment, an electrostatically spun fabric barrier may be added to the implant to act as a barrier to hyperplasia and tissue adhesion, thus reducing the possibility of postsurgical adhesions. The fabric barrier is preferably in the form of dense fibrous fabric that is added to the implant. Preferably, the fibrous fabric is comprised of small diameter fibers that are fused to the top and/or bottom surface of the biocompatible scaffold. This enables certain surface properties of the structure, such as porosity, permeability, degradation rate and mechanical properties, to be controlled.

[0085] One of ordinary skill in the art will appreciate that the fibrous fabric can be produced via an electrostatic spinning process in which a fibrous layer can be built up on lyophilized foam and nonwoven surfaces. This electrostatic spinning process may be conducted using a variety of fiber materials. Exemplary fiber materials include aliphatic polyesters. A variety of solvents may be used as well, including those identified above that are useful to prepare the polymer solution that forms the foam component.

[0086] The composition, thickness, and porosity of the fibrous layer may be controlled to provide the desired mechanical and biological characteristics. For example, the bioabsorption rate of the fibrous layer may be selected to provide a longer or shorter bioabsorption profile as compared to the underlying biocompatible scaffold. Additionally, the fibrous layer may provide greater structural integrity to the composite so that mechanical force may be applied to the fibrous side of the structure. In one embodiment the fibrous layer could allow the use of sutures, staples or various fixation devices to hold the composite in place. Generally, the fibrous layer has a thickness in the range of 1 micron to 1000 microns. However, for some applications such as rotator cuff and meniscus injury repair, the fibrous layer has a thickness greater than 1.5 mm.

[0087] The tissue repair implants of the present invention can be used in a variety of surgical and non-surgical applications. In some surgical applications, such as for use in the repair of a variety of tissues including a torn ligament, tendon, rotator cuff, nerve, skin, cartilage, or meniscus, the tissue implants ot the invention must be able to be handled in the operating room, and they must be able to be sutured or otherwise fastened without tearing. Additionally, the implants should have a burst strength adequate to reinforce the tissue, and the structure of the implant can be suitable to encourage tissue ingrowth. By way of non-limiting example, the scaffolds of the present invention can be highly porous to allow cell growth therein. Preferably, the median pore size is in the range of 100 to 500 microns. In these embodiments, the scaffold should be sufficiently pliable to accommodate tissue growth within the interior region of the scaffold, so that the geometry of the scaffold can be remodeled as tissue ingrowth increases. Accordingly, in the present invention, tissue can be grown on the surface of the biocompatible scaffold, or alternatively, tissue can be grown into and on the surface of the biocompatible scaffold, such that the tissue becomes embedded in and integrated with the scaffold.

[0088] In one embodiment ot the present invention, the tissue repair implant is used in the treatment of a tissue injury, such as injury to a ligament, tendon, nerve, skin, cartilage or meniscus. Repairing tissue injuries involves the steps of obtaining a sample of living tissue by any of the variety of techniques known to those having ordinary skill in the art, processing that sample of living tissue under sterile conditions, such as for example by cutting the tissue, to create at least one minced, finely divided tissue particle, depositing the tissue sample upon the biocompatible scaffold, such that the tissue sample becomes associated with the scaffold to form a tissue repair implant, and placing the tissue repair implant in a desired position relative to the tissue injury. Repairing tissue injuries may also involve placing the scaffold at the site of tissue injury and then depositing the fine tissue particles onto the scaffold. The cells in the tissue particles associated with the scaffold can migrate to the scaffold and begin proliferating and integrating with surrounding tissue at the site of implantation, thereby repairing the tissue injury. This method for repairing tissue injuries can include an additional, optional step. Prior to the step of placing the tissue repair implant in a desired position relative to the tissue injury, the scaffold and associated tissue particles can be incubated for a duration and under conditions effective to allow cells within the tissue particles to migrate from the tissue and begin populating the scaffold.

[0089] The tissue samples used in the present inven-

tion are obtained from a donor (autogenic, allogeneic, or xenogeneic) using appropriate harvesting tools. The tissue samples can be finely minced and divided into small particles either as the tissue is collected, or alternatively, the tissue sample can be minced after it is harvested and collected outside the body. In embodiments, where the tissue sample is minced after it is harvested, the tissue samples can be weighed and then washed three times in phosphate buffered saline. Approximately 300 to 500 mg of tissue can then be minced in the presence of a small quantity, such as, for example, about 1 ml, of a physiological buffering solution, such as, for example, phosphate buffered saline, or a matrix digesting enzyme, such as, for example, 0.2 % collagenase in Hams F12. Mincing the tissue divides the tissue into particles or small pieces of approximately 1mm^3. Mincing the tissue can be accomplished by a variety of methods. In one embodiment, the mincing is accomplished with two sterile scalpels using a parallel direction, and in another embodiment, the tissue can be minced by a processing tool that automatically divides the tissue into particles of a desired size. In one embodiment, the minced tissue can be separated from the physiological fluid and concentrated using any of a variety of methods known to those having ordinary skill in the art, such as for example, sieving, sedimenting or centrifuging. In embodiments where the minced tissue is filtered and concentrated, the suspension of minced tissue preferably retains a small quantity of fluid in the suspension to prevent the tissue from drying out. In another embodiment, the suspension of minced tissue is not concentrated, and the minced tissue can be directly delivered to the site of tissue repair via a high concentration tissue suspension or other carrier such as for example, a hydrogel, fibrin glue, or collagen. In this embodiment, the minced tissue suspension can be covered by any of the biocompatible scaffolds described above to retain the tissue fragments in place.

[0090] The minced tissue can then be distributed onto a scaffold using a cell spreader so as to cover the entire scaffold. In a preferable embodiment for meniscus and cartilage repair, the minced tissue is spread onto 4 X 5 cm scaffolds that have been presoaked in Dulbecco's modified Eagles medium (DMEM) so as to cover the entire scaffold. Optionally, the tissue particles can be adhered to the scaffolds using any of the adhesive agents described above, such as, for example, fibrin glue or platelet rich plasma. In embodiments using fibrin glue or platelet rich plasma, a few microliters of thrombin can be placed on the scaffolds, prior to distribution of fibrinogen or platelet rich plasma on the scaffolds, and allowed to set. Once the tissue particles and any additional agents have been deposited on the scaffold, the tissue repair implant can then implanted immediately, or alternatively, the implant can be cultured *in vitro* for a duration and under conditions sufficient to allow the cells in the tissue particles to migrate from the tissue particles onto the scaffold. In an embodiment where the tissue repair implant is incubated prior to implantation, the implant is preferably cultured *in vitro* for approximately 1- 3 weeks in a chondrocyte growth medium, such as for example, DMEM-high glucose, supplemented with 20% fetal calf serum (FCS), 10 mM HEPES, 0.1 mM nonessential amino acids, 20 mg/ml of L-proline, 50 mg/ml ascorbic acid, 100 mg/ml penicillin, 100 mg/ml of streptomycin and 0.25 mg/ml of amphotericin B.

[0091] The methods of repairing tissue injuries using the tissue implants according to the present invention can be conducted during a surgical operation to repair the tissue injury. Alternatively, the steps of processing the tissue sample to create minced, finely divided tissue particles, depositing the tissue particles upon the scaffold to form a tissue repair implant, and/or incubating the tissue repair implant prior to implantation can be conducted at another, sterile location prior to surgical placement of the implant relative to the site of injury.

[0092] The implants used to repair injured tissue can be of a size and shape such that they match the geometry and dimensions of a desired portion or lesion of the tissue to be treated. The implant can be sized and shaped to produce the necessary geometry by numerous techniques including cutting, folding, rolling, or otherwise manipulating the implant. As noted above, the biological component may be added to the scaffold during or after manufacture of the scaffold or before or after the implant is installed in a patient. An additional quantity of the biological component may be added after the implant is installed. Once access is made into the affected anatomical site (whether by minimally invasive, open or mini-open surgical technique), the implant can be affixed to a desired position relative to the tissue injury, such as within a tear or lesion. Once the implant is placed in the desired position or lesion, it can be affixed by using a suitable technique. In one aspect, the implant can be affixed by a chemical and/or mechanical fastening technique. Suitable chemical fasteners include glues and/or adhesive such as fibrin glue, fibrin clot, and other known biologically compatible adhesives. Suitable mechanical fasteners include sutures, staples, tissue tacks, suture anchors, darts, screws, pins and arrows. It is understood that combinations of one or more chemical and/or mechanical fasteners can be used. Alternatively, one need not use any chemical and/or mechanical fasteners. Instead, placement of the implant can be accomplished through an interference fit of the implant with an appropriate site in the tissue to be treated.

[0093] In another embodiment, the tissue repair implant is useful in surgical techniques that repair ligaments, tendons, skin and/or nerves. In one use, the tissue repair implant can be for repair and to augment tissue loss during tendon or ligament repair surgery or it can be used as a stand alone device. In the case of repair, tendon or ligament ends are approximated through appropriate surgical techniques and the tissue repair implant is used around the joined end to give more mechanical support and to enhance the healing response. As a result of the healing process, the tendon or ligament tissue grows

within the implant device, eventually maturing into a tissue with similar mechanical properties to that of native tissue. The implant provides the mechanical support that is initially necessary to ensure proper healing, and it also serves as a guide for tissue regeneration. In another use as a stand alone device, the ruptured tissue is removed, and the tissue repair implant with minced tissue serves to replace the function of the damaged tissue. The ruptured tissue can be the tissue source used for healing damaged tissue.

[0094] In embodiments where the tissue repair implant is used to repair ligament tissue, the tissue repair implant can be used for tissue augmentation, or alternatively, as a stand-alone device. In embodiments where the tissue repair implant is used for augmentation, the tissue repair implant can be used in conjunction with any of a variety of standard, established repair techniques known to those having ordinary skill in the art. In embodiments where the tissue repair implant is used for augmentation during ACL repair, surgeons currently use an autograft consisting of ligament tissue, bone-patellar tendons, tendon-bone tendons, hamstring tendons, or illotibial band to repair tissue, and the tissue repair implant of the present invention can be placed either around the autograft, surrounded by the autograft, or alongside the autograft. In embodiments where the tissue repair element is used as a stand-alone device, the ruptured ligament can be removed and completely replaced by the tissue repair implant. In this case, the tissue repair implant can be affixed to bone at each end of the implant. In the case of ACL repair, one end of the implant can be stabilized at the original origin site of the femur, while the other end can be placed at the original insertion site on the tibia.

[0095] The tissue repair implant can be utilized in a variety of configurations. For example, the implant can be folded or stacked in multiple laminates or it can be rolled into the shape or a tube-like structure. Tendon or ligament ends can be joined, for example, by suturing, stapling, clipping, adhering, or anchoring, the implant to ends of the implant. In some embodiments where the tissue repair implant is used to repair tendons, such as for example, rotator cuff repair, the surgeon can use the tissue repair implant to assist in the reapproximation of the torn rotator cuff to a bony trough through the cortical surface of the greater tuberosity. Often times, in older patients, the rotator cuff tissue is thin and degenerate and/or the quality of the humerus is osteoporotic. Therefore, in order to increase the strength of the attachment to the bony trough, the tissue repair implant can be placed on top of the tendon, such that the sutures would pass through both the scaffold and tendon, or alternatively, the tissue repair implant can be used on top of the bone bridge to prevent the sutures from pulling out of the bone. In either embodiment, the tissue repair implant provides suture retention strength. In situations where the quality of the rotator cuff is so degenerate that the tissue cannot be reapproximated to the humerus, the tissue repair implant can serve as a bridge, wherein one end of the implant can be joined to the remaining tendon while the other end can be attached to the bone.

[0096] In another variation, the implant can be used to repair or replace the sheath of a tendon. To do so, the implant is sutured or otherwise joined to the connective tissue, such as the periosteum, synovium, or muscle, and wrapped around the tendon. This construction allows free gliding of the tendon within the sheath formed by the implant. The implant provides the necessary structural support following surgery. Over time, however, the implant in this embodiment can be resorbed and replaced by new tissue.

[0097] The implants of the invention can also be used for organ repair replacement or regeneration strategies that may benefit from these unique tissue implants. For example, these implants can be used for spinal disc, cranial tissue, dura, nerve tissue, liver, pancreas, kidney, bladder, uterus, esophagus, liver spleen, cardiac muscle, skeletal muscle, skin, fascia, pelvic floor, stomach, tendons, cartilage, ligaments, and breast tissues.

[0098] The implants of the present invention can be used to create a biological assay for measuring the effect of a substance on living tissue. In this embodiment, tissue constructs are created, as described above, by providing a sterile, biocompatible scaffold, obtaining a sample of living tissue, processing the sample of living tissue under sterile conditions to form a suspension of minced tissue having minced tissue fragments and a physiological buffering solution, and depositing the suspension of minced tissue on the biocompatible scaffold such that the suspension of minced tissue and the scaffold become associated. The tissue construct is incubated under conditions that are effective to allow cells within the minced tissue to populate the scaffold. The tissue construct can then be contacted with the substance that is to be tested, and the effect(s) of that substance can be determined. These tissue constructs can be used to determine and/or test the biological responses to a test substance, such as for example, cell viability, growth, migration, differentiation and maintenance of cell phenotype, metabolic activity, induction or repression. These biological responses can be assayed using any of a variety of techniques known to those having ordinary skill in the art, such as for example, proliferation assay, cell migration assay, protein assay, gene expression assay, viability assay, calorimetric assay or metabolic assay. By way of non-limiting example, the expression of a selected gene(s) or gene products typically expressed by the tissue of the tissue construct, such as for example, the expression of type II, type IX or type XI collagen expressed by chondrocytes, using a variety known assays, such as for example, northern blot analysis, RNAse protection assays, polymerase chain reaction (PCR), western blot analysis and enzyme-linked immunoabsorbant assay (ELISA). Suitable substances that can be tested using the tissue constructs of the present invention include, but are not limited to, drugs, pharmaceutical compositions, chemicals, microbes, el-

ements, cytokines, growth factors, hormones, antibodies, peptides, ligands, antagonists of membrane-bound receptors, and combinations thereof.

[0099] The implants of the present invention can also be used as a delivery device for a therapeutic. wherein the therapeutic is the minced tissue, which includes a combination of cells, extracellular matrix and inherent growth factors. The scaffold portion of the implant can allow for hormones and proteins to be released into the surrounding environment.

[0100] The methods of repairing tissue injuries using the tissue implants according to the present invention can be conducted during a surgical operation to repair the tissue injury. A patient is prepared for tissue repair surgery in a conventional manner using conventional surgical techniques. Tissue repair is performed at the site of injured tissue using the tissue repair implants of the present invention. The tissue sample used to form the tissue repair implant is obtained from the patient (or another donor) using appropriate tools and techniques. The tissue sample is finely minced and divided into at least one tissue particle having a particle size in the range of 0.1 to 3 mm^3. The tissue can be minced using a conventional mincing technique such as two sterile scalpels used in a parallel direction. Between 300 to 500 mg of tissue is minced in the presence of about 1 ml of a physiological buffering solution, depending on the extent of the tissue injury at the site of repair. The minced tissue is filtered and concentrated to separate the minced tissue particle from the physiological buffering solution. The minced tissue can be concentrated using any of a variety of conventional techniques, such as for example, sieving, sedimenting or centrifuging. The minced tissue particles are then distributed using a cell spreader onto a 4 X 5 cm biocompatible scaffold that has been soaked in Dulbecco's modified Eagles medium (DMEM). An adhesion agent can be added to the biocompatible scaffold and the minced tissue particles. The tissue repair implant is implanted at the site of tissue injury, either immediately or after a period of *in vitro* incubation. Final wound closure is performed in a conventional manner using conventional surgical techniques.

[0101] The following examples are illustrative of the principles and practice of this invention. Numerous additional embodiments within the scope of the claims will become apparent to those skilled in the art.

EXAMPLE 1

[0102] Healthy cartilage tissue from articulating joints was obtained from bovine shoulders. The cartilage tissue, which was substantially free of bone tissue, was minced using scalpel blades to obtain small tissue fragments in the presence of 0.2 % collagenase. The size of the tissue fragments varied but on average should be approximately 1 x 1 mm in dimension. The minced tissue was then distributed uniformly on a 4x5 cm synthetic bioresorbable polycaprolactone/polyglycolic acid (PCL /PGA) scaffold. Ethylene oxide sterilized polymer scaffolds, were pre-soaked for 4 hours in Dulbecco's Modified Eagle's Medium prior to distribution of tissue fragments. The scaffold loaded with minced fragments was then placed in a 10cm cell culture dish containing chondrocyte growth medium. The chondrocyte growth medium consisted of Dulbecco's modified eagles medium (DMEM-high glucose) supplemented with 20% fetal calf serum (FCS), 10 mM HEPES, 0.1 mM nonessential amino acids, 20 mg/ml of L-proline, 50 mg/ml ascorbic acid, 100 mg/ml penicillin, 100 mg/ml of streptomycin and 0.25 mg /ml of amphotericin B. The growth medium was replenished every other day. Scaffolds were cultured at 37°C in a cell culture incubator. Six weeks following culture samples were removed and analyzed for cell distribution and migration within the scaffolds and for production of cartilage like matrix. FIG. 1 demonstrates that cells migrate extensively into the polymer scaffolds from the minced cartilage tissue fragments (FIG.1A). The migrating cells retain their phenotype and produce matrix that stained positive for the sulfated glycosaminoglycans using the Safranin O stain (FIG. 1B).

EXAMPLE 2

[0103] The bioresorbable scaffolds containing minced cartilage tissue and cells from Example 1 were also implanted into SCID mice. The objective was to evaluate the chondrocytic ingrowth of minced cartilaginous tissues into polymer scaffolds in vivo. Polymer scaffolds 5 mm in diameter, were subcutaneously implanted bilaterally in the lateral thoracic region of SCID mice. The implanted scaffold was permitted to support cell growth for four weeks. The subcutaneous implantation sites with their overlying skin were then excised and preserved in 10% buffered formalin fixative. Following fixation, each implantation site was processed for histology. Histological sections were stained with Hematoxylin and eosin, and Safranin-O. FIGS. 2 A and B show that abundant cells were distributed within the scaffold. The cells displayed chondrocyte-like morphology, as evidenced by the intense positive staining for Safranin O of the synthesized matrix.

EXAMPLE 3

[0104] Minced cartilage tissue prepared according to the method described in Example 1 was distributed uniformly on a 4 X 5 cm synthetic bioresorbable polycaprolactone/polyglycolic acid (PCL/PGA) scaffold. Minced cartilage tissue fragments were adhered to the scaffolds with 1 mL of platelet rich plasma (PRP, Human). Sixty microliters (60 units) of thrombin were used to induce clot formation in the PRP. Control scaffolds loaded with minced cartilage fragments alone and scaffolds loaded with minced cartilage fragments adhered by PRP, were cultured *in vitro* for 1 week, and then implanted into SCID mice as described in the Example 2. FIG. 3A is a phot-

omicrograph of a control scaffold loaded with minced tissue. FIG. 3B is a photomicrograph depicting a scaffold loaded with minced tissue and PRP. FIG. 3B demonstrates that PRP is beneficial in promoting the migration of the chondrocyte cells, and PRP is also beneficial in promoting the maintenance of the differentiated phenotype of the chondrocyte cells within the scaffolds. The migrating cells retain their phenotype and produce matrix that stained positive for the sulfated glycosaminoglycans using the Safranin O stain (FIG. 3B).

EXAMPLE 4

[0105] Healthy full-thickness skin samples, collected from 1x1 cm wounds created on the dorsal side of the pigs, were immediately placed in 50 ml conical tubes containing DMEM with 10x antibiotics/antimycotics. Tissue samples were rinsed once in PBS containing 10x antibiotic/antimycotics followed by an additional rinsing step with PBS containing 1x antibiotics/antimycotics. The tissue was minced aseptically using a scalpel blade in a laminar flow hood. Dispersed skin samples were subjected to enzymatic digestion with 1 ml of 0.25% collagenase/0.25% dispase at 37°C for 15 min (Autologous cell dispersion #1). Another set of samples were first digested with 500 µl of 0.25% trypsin for 10 min, then washed with PBS to remove trypsin, and then incubated with 1 ml of 0.25% collagenase/0.25% dispase at 37°C for 15 min (Autologous cell dispersion #2). Following digestion, the samples were centrifuged at 2500 rpm for 5 min. The supernatant was aspirated and discarded. Dispersed, partially digested skin samples were washed once in PBS and then re-suspended in 500 µl of PBS. Approximately 20 µl of cell suspension was distributed evenly in the wound bed and bioresorbable scaffold was carefully applied on the top of dispersed cells making sure not to dislodge the cell suspension. Dispersed cells could be distributed evenly on the scaffold and placed onto the wound bed. FIG. 4 demonstrates that autologous cell dispersion was present histologically as keratinocyte "islands," some of which had migrated throughout the scaffold towards the wound surface.

EXAMPLE 5

[0106] Healthy anterior cruciate ligament tissue was obtained from bovine knees. The ligament tissue was minced using scalpel blades and/or scissors to obtain small tissue fragments. While the size of the tissue fragments varied, the average particle size was approximately 1mm^3 in dimension. In this example, the ligament was minced with and without 0.2 % collagenase. The minced tissue was then distributed uniformly on a 4x5 cm synthetic bioresorbable polycaprolactone/polyglycolic acid PGA/PCL scaffold or polylactic acid/polyglycolic acid (PLA/PGA) scaffold. The scaffolds were sterilized in 70% ethanol for our hour and washed three times with sterile PBS. The scaffolds were then pre-soaked for 1-2 hours in Dulbecco's Modified Eagle's Medium with 1 x antibiotic-antimycotic prior to distribution of tissue fragments. The scaffold loaded with minced fragments was then placed in a 10cm cell culture dish containing growth medium, which consisted of Dulbecco's modified eagles medium (DMEM-high glucose) supplemented with 20% fetal calf serum (FCS), 100 mg/ml penicillin, 100 mg/ml of streptomycin and 0.25 mg/ml of amphotericin B. Scaffolds with the minced tissue were cultured at 37°C in a cell culture incubator and the growth medium was exchanged every other day. Three and six weeks following culture, samples were removed and analyzed for cell distribution and migration within the scaffolds. FIG. 5 demonstrates cells migrating extensively into the polymer scaffolds after 6 weeks in culture from the minced anterior cruciate tissue fragments treated with collagenase (FIG. 5A) and without collagenase (FIG. 5B).

EXAMPLE 6

[0107] Menisci were harvested from adult Goat knees and 4mm diameter explants (2mm thick) were taken from the white and red/white regions. A 2 mm punch biopsy was removed from the center of the explants. A bioresorbable scaffold polylactic acid/polycaprolactone (PLA/PCL) 2 mm in diameter and 2 mm thick was inserted into the center of the meniscal explant. The explants with scaffolds were cultured for 2 and 3 weeks under standard cell culture conditions with changes in media (DMEM containing 1% FBS, 1x antibiotic-antimycotic) occurring every other day. At 14 and 21 days following culture, half the samples were placed into 10% buffered formalin for histological processing. Sections were stained with Hematoxylin to visualize the cells. From the remaining samples the scaffolds were removed and cell number estimated by quantitation of DNA using the CyQuant assay. FIG. 6A demonstrates that there is cell migration into the polymer scaffolds from the meniscal explants. FIG. 6B shows the histology of cross sections of scaffolds demonstrating cell migration into scaffolds.

EXAMPLE 7

[0108] Healthy cartilage tissue and osteochondral plugs were obtained from articulating joints of bovine shoulders. Minced cartilage tissue was prepared according to the method described in Example 1. in addition, osteochondral plugs (1x1 cm) were harvested from bovine shoulders using a diamond bone saw and morselized with bone cutters to obtain bone cartilage paste. Next, 250 mg of the sample (minced cartilage or bone cartilage paste) was distributed on 2x5 cm synthetic bioresorbable (PCL/PGA) scaffolds. The scaffold loaded with minced cartilage fragments or osteochondral paste was then placed in a 10 cm cell culture dish containing chondrocyte growth medium and cultured in a cell culture incubator as described in Example 1. Three weeks following culture the samples were removed and implanted

into SCID mice as described in Example 2. The objective was to evaluate the nature of tissue formed within the scaffold following implantation for 4 weeks. Histological sections were analyzed for cell distribution and for the nature of the matrix formed, within the scaffolds, by staining with Hematoxylin and eosin (H/E), Safranin O (SO) and Modified Mallory's Aniline Blue (MMAB). FIGS. 7A - 7C demonstrate that cells migrate extensively into the polymer scaffolds from the minced cartilage tissue fragments and form cartilage like matrix that stains positive for Safranin O. This is particularly evident in FIG. 7B in which the darker area in the center and top of the photograph is indicative of positive staining. FIGS. 8A - 8C demonstrate that cells migrate from bone cartilage paste into polymer scaffolds. However, the tissue that is formed comprises cartilage as well as new bone. The appearance of the new bone is indicated by the lighter arrows in FIG. 8C while the old bone fragments are indicated by the darker arrows in FIGS. 8 A and 8C.

EXAMPLE 8

[0109] Healthy cartilage tissue was obtained from articulating joints of bovine shoulders. Minced cartilage tissue was prepared according to the method described in Example 1. Biopsy punches were used to obtain cartilage tissue fragments 2 mm and 3 mm in diameter. The thickness of these fragments was approximately 1mm. 250 mg of minced cartilage or cartilage fragments 2 or 3 mm in diameter were distributed on 2x5 cm synthetic bioresorbable (PCL /PGA) scaffold. The scaffold loaded with cartilage fragments was then placed in a 10 cm cell culture dish containing chondrocyte growth medium and cultured in a cell culture incubator as described in Example 1. Three weeks following culture samples were removed and cell number estimated by quantitation of DNA content. 5 mm biopsy punches were also implanted into SCID mice as described in Example 2. The objective was to evaluate the optimal size of tissue fragments for this process. FIG. 9 demonstrates that the highest cell number was observed in scaffolds loaded with minced cartilage tissue and the lowest in scaffolds loaded with cartilage fragments 3 mm in diameter. FIGS. 10A - 10C provide histological evaluations of scaffolds implanted into SCID mice and stained with Safranin O. These results demonstrate that uniform cartilage-like tissue (stained, darker areas) in scaffolds loaded with minced cartilage tissue and cartilage fragments 2 mm in diameter (FIGS. 10A and B). Scaffolds that were loaded with cartilage fragments 3 mm in diameter were not uniformly filled (FIG. 10C).

[0110] One of ordinary skill in the art will appreciate further features and advantages of the invention based on the above-described embodiments. Accordingly, the invention is not to be limited by what has been particularly shown and described, except as indicated by the appended claims.

Claims

1. A tendon or ligament repair implant, comprising:

   a biocompatible scaffold having an aspect ratio greater than 1; and
   at least one minced tissue particle associated with at least a portion of the scaffold, the at least one tissue particle derived from ligament tissue or tendon tissue and including viable cells that can migrate from the tissue fragment onto the scaffold.

2. The implant of claim 1, wherein the scaffold has a cylindrical shape or an elliptical shape.

3. The implant of claim 1, wherein the aspect ratio of the scaffold is in the range of greater than 2 and less than 100.

4. The implant of claim 1, wherein the scaffold is made from a copolymer of 95:5 lactide and glycolide.

5. The implant of claim 1, wherein the scaffold is made from polymers or copolymers formed from monomers selected from the group consisting of lactide, glycolide, dioxanone, and caprolactone.

6. The implant of claim 1, wherein the implant includes natural polymers selected from the group consisting of collagen, fibrin, and silk.

7. The implant of claim 2, wherein the implant includes strips of collagen or silk present within an inner portion of the scaffold or on a peripheral portion of the scaffold.

8. The implant of claim 1, wherein the scaffold has a diameter in the range of 3 to 12 mm.

9. The implant of claim 1, wherein the scaffold has a tensile strength and an elastic modulus similar to that of native tendon or ligament tissue.

10. The implant of claim 9, wherein the tensile strength of the scaffold is in the range of 1000N to 2500N.

11. The implant of claim 9, wherein the elastic modulus of the scaffold is in the range of 150N/m to 200N/m.

12. The implant of claim 1, wherein the scaffold has a slow resorption profile.

13. The implant of claim 12, wherein the resorption profile of the scaffold spans at least three months.

14. The implant of claim 1, wherein the scaffold is formed from a foam component reinforced with a mesh com-

ponent.

15. The implant of claim 14, wherein the mesh component includes polydioxanone and the foam component is a copolymer of 35:65 ε-caprolactone and glycolide.

16. The implant of claim 14, wherein the scaffold has an open pore structure with pores having a size sufficient to allow cell and tissue ingrowth.

17. The implant of claim 16, wherein the pores have an average diameter in the range of 50 to 1000 microns.

18. The implant of claim 14, wherein the foam component has a thickness in the range of 300 microns to 2 mm.

19. The implant of claim 14, wherein the mesh component has a mesh density in the range of 12% to 80%.

20. The implant of claim 1, wherein the scaffold is formed of plurality of filaments.

21. The implant of claim 20, wherein the majority of fibers that form the filaments are aligned in a longitudinal direction.

22. The implant of claim 1, wherein the scaffold is formed from a material selected from the group consisting of a knit material, a woven material, and a braided material.

23. The implant of claim 14, wherein the mesh is formed on the outer surface of the scaffold.

24. The implant of claim 23, wherein the mesh is a knit or a woven structure.

25. The implant of claim 23, wherein the mesh is biodegradable and biocompatible.

26. The implant of claim 1, further comprising an autograft selected from the group consisting of ligament tissue, bone-patellar tendons, tendon-bone tendons, hamstring tendons, or iliotibial band.

27. The implant of claim 26, wherein the implant and the autograft are configured in an orientation selected from the group consisting of the implant being placed around the autograft, the implant being surrounded by the autograft, and the implant being placed alongside the autograft.

28. The implant of claim 1, wherein the biocompatible scaffold further comprises at least one additional biological component applied thereto.

29. The implant of claim 28, wherein the at least one additional biological component comprises growth factors, matrix proteins, peptides, antibodies, enzymes, cytokines, viruses, nucleic acids, peptides, isolated cells, platelets, and combinations thereof.

30. The implant of claim 1, wherein the biocompatible scaffold further comprises an adhesion agent for anchoring the at least one tissue fragment to the biocompatible scaffold.

31. The implant of claim 30, wherein the adhesion agent comprises an anchoring agent selected from the group consisting of hyaluronic acid, fibrin glue, fibrin clot, collagen gel, gelatin-resorcin-formalin adhesive, mussel-based adhesive, dihydroxyphenyialanine (DOPA) based adhesive, chitosan, transglutaminase, poly(amino acid)-based adhesive, cellulose-based adhesive, synthetic acrylate-based adhesives, platelet rich plasma (PRP), Matrigel, Monostearoyl Glycerol co-Succinate (MGSA), Monostearoyl Glycerol co-Succinate/polyethylene glycol (MGSA/PEG) copolymers, laminin, elastin, proteoglycans, and combinations thereof.

32. The implant of claim 30, wherein the adhesion agent comprises a cross-linking agent selected from the group consisting of divinyl sulfone (DVS), polyethylene glycon divinyl sulfone (VS-PEG-VS), hydroxyethyl methacrylate divinyl sulfone (HEMA-DIS-HEMA), formaldehyde, glutaraldehyde, aldehydes, isocyanates, alkyl and aryl halides, imidoesters, N-substituted maleimides, acylating compounds, carbodiimide, hydroxychloride, N-hydroxysuccinimide, light, pH, temperature, and combinations thereof.

Patentansprüche

1. Sehnen- oder Bandreparaturimplantat, welches umfasst:

   ein biokompatibles Stützgerüst mit einem Längenverhältnis von größer als 1; und
   wenigstens ein zerkleinertes Gewebeteilchen, das mit wenigstens einem Bereich des Stützgerüsts verbunden ist, wobei das wenigstens eine Gewebeteilchen aus Bandgewebe oder Sehnengewebe herrührt und lebensfähige Zellen einschließt, die aus dem Gewebefragment auf das Stützgerüst migrieren können.

2. Implantat nach Anspruch 1, wobei das Stützgerüst eine zylindrische Form oder eine elliptische Form aufweist.

3. Implantat nach Anspruch 1, wobei das Längenverhältnis des Stützgerüsts im Bereich von größer als

2 und kleiner als 100 ist.

4. Implantat nach Anspruch 1, wobei das Stützgerüst hergestellt ist aus einem Copolymer aus 95:5 Laktid und Glycolid.

5. Implantat nach Anspruch 1, wobei das Stützgerüst hergestellt ist aus Polymeren oder Copolymeren, die aus Monomeren gebildet sind, die ausgewählt sind aus der Gruppe bestehend aus Laktid, Glycolid, Dioxanon und Caprolacton.

6. Implantat nach Anspruch 1, wobei das Implantat natürliche Polymere einschließt, die ausgewählt sind aus der Gruppe bestehend aus Collagen, Fibrin und Seide.

7. Implantat nach Anspruch 2, wobei das Implantat Streifen aus Collagen oder Seide einschließt, die innerhalb eines inneren Bereichs des Stützgerüsts oder auf einem peripheren Bereich des Stützgerüsts vorliegen.

8. Implantat nach Anspruch 1, wobei das Stützgerüst einen Durchmesser im Bereich von 3 bis 12 mm aufweist.

9. Implantat nach Anspruch 1, wobei das Stützgerüst eine Zugfestigkeit und einen Elastizitätsmodul ähnlich zu demjenigen von natürlichem Sehnen- oder Bandgewebe aufweist.

10. Implantat nach Anspruch 9, wobei die Zugfestigkeit des Stützgerüsts im Bereich von 1000 N bis 2500 N ist.

11. Implantat nach Anspruch 9, wobei der Elastizitätsmodul des Stützgerüsts im Bereich von 150 N/m bis 200 N/m ist.

12. Implantat nach Anspruch 1, wobei das Stützgerüst ein langsames Resorptionsprofil aufweist.

13. Implantat nach Anspruch 12, wobei das Resorptionsprofil des Stützgerüsts wenigstens drei Monate überspannt.

14. Implantat nach Anspruch 1, wobei das Stützgerüst gebildet ist aus einer Schaumkomponente, die mit einer Netzkomponente verstärkt ist.

15. Implantat nach Anspruch 14, wobei die Netzkomponente Polydioxanon einschließt und die Schaumkomponente ein Copolymer aus 35:65 ε-Caprolacton und Glycolid ist.

16. Implantat nach Anspruch 14, wobei das Stützgerüst eine offene Porenstruktur mit Poren mit einer Größe aufweist, die ausreichend ist, um Zell- und Gewebeeinwuchs zu ermöglichen.

17. Implantat nach Anspruch 16, wobei die Poren einen durchschnittlichen Durchmesser im Bereich von 50 bis 1000 Mikrometern aufweisen.

18. Implantat nach Anspruch 14, wobei die Schaumkomponente eine Dicke im Bereich von 300 Mikrometer bis 2 mm aufweist.

19. Implantat nach Anspruch 14, wobei die Netzkomponente eine Maschendichte im Bereich von 12% bis 80% aufweist.

20. Implantat nach Anspruch 1, wobei das Stützgerüst aus einer Vielzahl von Filamenten gebildet ist.

21. Implantat nach Anspruch 20, wobei die Mehrzahl der Fasern, die die Filamente bilden, in einer Längsrichtung ausgerichtet ist.

22. Implantat nach Anspruch 1, wobei das Stützgerüst gebildet ist aus einem Material, das ausgewählt ist aus der Gruppe bestehend aus Strickmaterial, einem gewebten Material und einem geflochtenen Material.

23. Implantat nach Anspruch 14, wobei das Netz gebildet ist auf einer äußeren Oberfläche des Stützgerüsts.

24. Implantat nach Anspruch 23, wobei das Netz eine gestrickte oder eine gewebte Struktur ist.

25. Implantat nach Anspruch 23, wobei das Netz bioabbaubar und biokompatibel ist.

26. Implantat nach Anspruch 1, weiter umfassend ein Autotransplantat, das ausgewählt ist aus der Gruppe bestehend aus Bandgewebe, Knochen-Kniescheibe-Sehnen, Sehnenknochen-Sehnen, Kniebeugersehnen oder Maissiat'schem Streifen.

27. Implantat nach Anspruch 26, wobei das Implantat und das Autotransplantat konfiguriert sind in einer Ausrichtung, die ausgewählt ist aus der Gruppe bestehend aus dem Implantat, das um das Autotransplantat herum angeordnet ist, dem Implantat, das von dem Autotransplantat umgeben ist, und dem Implantat, daß längsseits des Autotransplantats angeordnet ist.

28. Implantat nach Anspruch 1, wobei das biokompatibie Stützgerüst ferner wenigstens eine zusätzliche biologische Komponente, die darauf aufgetragen ist, umfasst.

29. Implantat nach Anspruch 28, wobei die wenigstens eine zusätzliche biologische Komponente Wachsfaktoren, Matrixproteine, Peptide, Antikörper, Enzyme, Cytokine, Viren, Nukleinsäuren, Peptide, isolierte Zellen, Blutplättchen und Kombinationen derselben umfasst.

30. Implantat nach Anspruch 1, wobei das biokompatible Stützgerüst ferner ein Haftmittel zum Verankern des wenigstens einen Gewebefragments an dem biokompatiblen Stützgerüst umfasst.

31. Implantat nach Anspruch 30, wobei das Haftmittel ein Verankerungsmittel umfasst, das ausgewählt ist aus der Gruppe bestehend aus Hyaluronsäure, Fibrinkleber, Fibringerinnsel, Kollagengel, Gelatine-Resorzin-Formalin-Haftmittel, Haftmittel auf Muschelbasis, Haftmittel auf Dihydroxyphenylalaninbasis (DOPA), Chitosan, Transglutaminase, Haftmittel auf Basis von Poly(aminosäure), Haftmittel auf Basis von Cellulose, Haftmittel auf Basis von synthetischem Acrylat, blutplättchenreichem Plasma (PRP), Matrigel, Monostearoylglycerol-co-Succinat (MGSA), Monostearoylglycerol-co-Succinat/Polyethylenglykol-copolymere (MGSA/PEG), Laminin, Elastin, Proteoglycane und Kombinationen derselben.

32. Implantat nach Anspruch 30, wobei das Haftmittel ein Vernetzungsmittel umfasst, das ausgewählt ist aus der Gruppe bestehend aus Divinylsulfon (DVS), Polyethylenglycondivinylsulfon (VS-PEG-VS), Hydroxyethylmethacrylatdivinylsulfon (HEMA-DISHEMA), Formaldehyd, Glutaraldehyd, Aldehyden, Isocyanaten, Alkyl- und Arylhalogeniden, Imidoestern, N-substituierten Maleimiden, acylierenden Verbindungen, Carbodiimid, Hydroxychlorid, N-Hydroxysuccinimid, Licht, pH, Temperatur und Kombinationen derselben.

Revendications

1. Implant pour la réparation de tendons ou de ligaments, qui comprend :

   un support biocompatible ayant un rapport de côtés supérieur à 1 ; et
   au moins une particule de tissu broyé associée à au moins une partie du support, la au moins une particule de tissu provenant de tissu ligamentaire ou de tissu tendineux, et comprenant des cellules viables qui peuvent migrer du fragment de tissu sur le support.

2. Implant selon la revendication 1, dans lequel le support a une forme cylindrique ou une forme elliptique.

3. Implant selon la revendication 1, dans lequel le rapport de côtés du support se trouve dans la plage allant de plus de 2 à moins de 100.

4. Implant selon la revendication 1, dans lequel le support est formé par un copolymère de lactide et de glycolide à 95/5.

5. Implant selon la revendication 1, dans lequel le support est formé par des polymères ou des copolymères formés par des monomères choisis dans le groupe constitué par le lactide, le glycolide, le dioxanone, et la caprolactone.

6. Implant selon la revendication 1, dans lequel l'implant comprend des polymères naturels choisis dans le groupe constitué par le collagène, la fibrine, et la soie.

7. Implant selon la revendication 2, dans lequel l'implant comprend des bandes de collagène ou de soie présentes à l'intérieur d'une partie interne du support ou sur une partie périphérique du support.

8. Implant selon la revendication 1, dans lequel le support a un diamètre dans la plage allant de 3 à 12 mm.

9. Implant selon la revendication 1, dans lequel le support a une résistance à la traction et un module d'élasticité similaires à ceux du tissu tendineux ou ligamentaire natif.

10. Implant selon la revendication 9, dans lequel la résistance à la traction du support se trouve dans la plage allant de 1 000 N à 2 500 N.

11. Implant selon la revendication 9, dans lequel le module d'élasticité du support se trouve dans la plage allant de 150 N/m à 200 N/m.

12. Implant selon la revendication 1, dans lequel le support à un profil de résorption lent.

13. Implant selon la revendication 12, dans lequel le profil de résorption du support couvre au moins trois mois.

14. Implant selon la revendication 1, dans lequel le support est formé par un composant de mousse renforcé par un composant de filet.

15. Implant selon la revendication 14, dans lequel le composant de filet comprend du polydioxanone et le composant de mousse est un copolymère de ε-caprolactone et de glycolide à 35/65.

16. Implant selon la revendication 14, dans lequel le support a une structure à pores ouverts avec des pores ayant une taille suffisante pour permettre la crois-

sance de la cellule et du tissu.

17. Implant selon la revendication 16, dans lequel les pores ont un diamètre moyen dans la plage allant de 50 à 1000 microns.

18. Implant selon la revendication 14, dans lequel le composant de mousse a une épaisseur dans la plage allant de 300 microns à 2 mm.

19. Implant selon la revendication 14, dans lequel le composant de filet a une densité du filet dans la plage allant de 12 % à 80 %.

20. Implant selon la revendication 1, dans lequel le support est formé par une pluralité de filaments.

21. Implant selon la revendication 20, dans lequel la majorité des fibres qui forment les filaments sont alignées dans un sens longitudinal.

22. Implant selon la revendication 1, dans lequel le support est formé à partir d'un matériau choisi dans le groupe constitué par un matériau tricoté, un matériau tissé, et un matériau tressé.

23. Implant selon la revendication 14, dans lequel le filet est formé sur la surface extérieure du support.

24. Implant selon la revendication 23, dans lequel le filet est une structure tricotée ou tissée.

25. Implant selon la revendication 23, dans lequel le filet est biodégradable et biocompatible.

26. Implant selon la revendication 1, comprenant en outre une autogreffe choisie dans le groupe constitué par un tissu ligamentaire, des os-tendons rotuliens, des tendon-tendons osseux, des tendons du jarret, ou la bandelette de Maissiat.

27. Implant selon la revendication 26, dans lequel l'implant et l'autogreffe sont configurés dans une orientation choisie dans le groupe constitué par l'implant étant placé autour de l'autogreffe, l'implant étant entouré par l'autogreffe, et l'implant étant placé le long de l'autogreffe.

28. Implant selon la revendication 1, dans lequel le support biocompatible comprend en outre au moins un composant biologique supplémentaire appliqué à celui-ci.

29. Implant selon la revendication 28, dans lequel le au moins un composant biologique supplémentaire comprend des facteurs de croissance, des protéines matricielles, des peptides, des anticorps, des enzymes, des cytokines, des virus, des acides nucléiques, des cellules isolées, des plaquettes, et des combinaisons de ceux-ci.

30. Implant selon la revendication 1, dans lequel le support biocompatible comprend en outre un agent d'adhésion pour ancrer le au moins un fragment de tissu au support biocompatible.

31. Implant selon la revendication 30, dans lequel l'agent d'adhésion comprend un agent d'ancrage choisi dans le groupe constitué par l'acide hyaluronique, la colle fibrine, un caillot de fibrine, du gel de collagène, un adhésif de gélatine-résorcine-formaline, un adhésif à base de moules, un adhésif à base de dihydroxyphénylalanine (DOPA), le chitosane, la transglutaminase, un adhésif à base de poly(acides aminés), un adhésif à base cellulose, des adhésifs à base d'acrylate synthétique, du plasma riche en plaquettes (PRP), le Matrigel, du monostéaroyl glycérol co-succinate (MGSA), des copolymères de monostéaroyl glycérol co-succinate/polyéthylèneglycol (MGSA/PEG), la laminine, l'élastine, les protéoglycanes, et des combinaisons de ceux-ci.

32. Implant selon la revendication 30, dans lequel l'agent d'adhésion comprend un agent de réticulation choisi dans le groupe constitué par la divinylsulfone (DVS), le polyéthylène glycol divinylsulfone (VS-PEG-VS), l'hydroxyéthyl méthacrylate divinylsulfone (HEMA-DIS-HEMA), le formaldéhyde, le glutaraldéhyde, les aldéhydes, les isocyanates, les alkyl et aryl halogénures, les imidoesters, les maléimides N-substitués, les composés d'acylation, le carbodiimide, l'hydroxychlorure, le N-hydroxysuccinimide, la lumière, le pH, la température, et des combinaisons de ceux-ci.

FIG. 1A

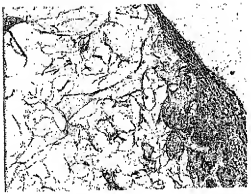


FIG. 1B

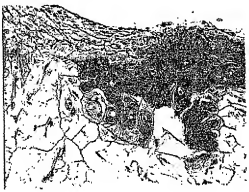


FIG. 2A

FIG. 2B

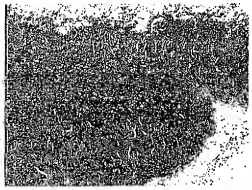


FIG. 3A

FIG. 3B

FIG. 4

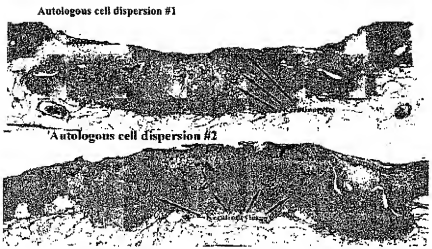

Autologous cell dispersion #1
Autologous cell dispersion #2

FIG. 5A

FIG. 5B

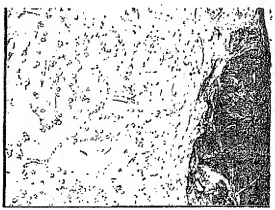


FIG. 6A

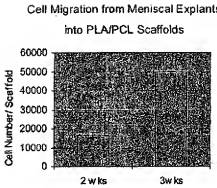

Cell Migration from Meniscal Explants
into PLA/PCL Scaffolds
Cell Number/ Scaffold
60000
50000
40000
30000
20000
10000
0
2 wks
3wks

FIG. 6B

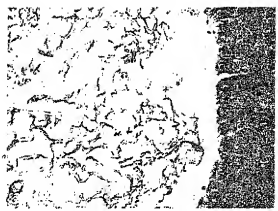


FIG. 7A

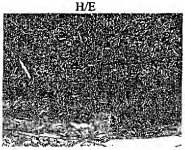


FIG. 7B

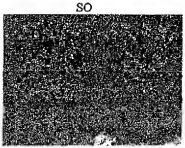
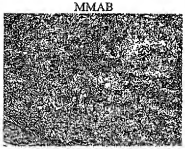


FIG. 7C



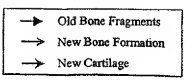


FIG. 8A

FIG. 8B

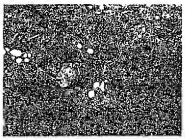


FIG. 8C

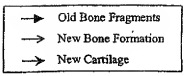


FIG. 9

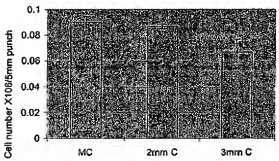


FIG. 10A

Minced Cartilage

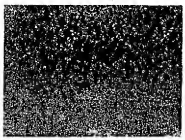


FIG. 10B

Cartilage 2mm

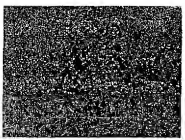


FIG. 10C

Cartilage 3mm